PB-245 116

STORAGE OF WASTES FROM WATERCRAFT AND DISPOSAL AT SHORE FACILITIES

Sheldon Cohen

General Dynamics Corporation

Prepared for:

Federal Water Pollution Control Administration

April 1970

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STORAGE OF WASTES FROM WATERCRAFT AND DISPOSAL AT SHORE FACILITIES

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1 Accession Number	2 Subject Field & Group	SELECTED WATER RESOURCES ABSTRACTS INPUT TRANSACTION FORM

5 Organization

General Dynamics' Electric Boat division, Groton, Connecticut

6 Title

STORAGE OF WASTES FROM WATERCRAFT AND DISPOSAL AT SHORE FACILITIES

10 Author(s)	11 Date	12 Pages	15 Contract Number
Cohen, Sheldon	APRIL, 1970	67	FWPCA CONTRACT NO. 14-12-509
	16 Project Number 15020DHB03/70		21 Note

22 Citation

23 Descriptors (Starred First)

*Water pollution control
*Water management (Applied)
*Capital costs
Operating costs
Holding tank
Sewage disposal

25 Identifiers (Starred First)

27 Abstract

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Sea water flushing was used for the water closets and urinal, but water conservation was used in the form of specially designed sanitary flush control and galley sink volume control devices to allow the use of a relatively small (120 gallon capacity) holding tank. The corrosion-resistant tank was provided with a level sensing system, an odor controlled vent line, an automatic flushing system, and a high level alarm. Shore-side transfer of the impounded wastes by suction pump-out of the tank via a quick-connect deck fitting was demonstrated. Solid galley waste was stored in a specially designed trash compactor.

All components and subsystems performed effectively and reliably throughout the test phase. The system was judged simple to operate and requires minimal operating attention and maintenance.

This report is submitted in fulfillment of Contract No. 14-12-509 between the Federal Water Pollution Control Administration and General Dynamics' Electric Boat Division.

Abstractor: Sheldon Cohen
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WR;102 (REV. OCT. 1968)
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STORAGE OF WASTES FROM WATERCRAFT AND DISPOSAL AT SHORE FACILITIES

ENVIRONMENTAL PROTECTION AGENCY
WATER QUALITY OFFICE

by

GENERAL DYNAMICS
Electric Boat Division
Eastern Point Road, Groton, Connecticut 06340

Program No. 15020DHB03/70

Contract No. 14-12-509

April 1970

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ABSTRACT

This program was undertaken to establish the effectiveness and acceptability of a watercraft impoundment system in controlling the principal waste sources, sanitary and galley waste, with disposal at a shore facility. A demonstration unit was designed, built, and installed by Electric Boat on a commercial tugboat, and operationally tested and evaluated under routine working conditions for a period of two months. Results of the test data were analyzed, and component performance and system effectiveness were evaluated. Equipment and installation costs, as well as system operating costs, were identified.

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SECTION 1

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The demonstration unit installed and operationally tested onboard the Three Deuces proved to be a practicable and acceptable system for the impoundment and shore-side transfer of sanitary and galley wastes. All components and subsystems performed effectively and reliably throughout the test phase. Specific conclusions regarding the system's relevant performance characteristics as well as its general acceptability and applicability are discussed below.

Specific Performance Characteristics

The sanitary and galley volume control devices increased the effective capacity of a relatively compact (nominal 120-gallon capacity) holding tank to an acceptable level.

Electronically controlled sanitary flush control valves with provisions for a dual flush and subsequent valve deactivation (2 to 4 minutes) were used in conjunction with a self-closing galley sink faucet. These devices combined to reduce the total waste volume accumulation rate an estimated 50 percent to an observed 7.5 gallons/man-day, under normal operating conditions. This rate is equivalent to an average pump-out interval of 3.0 days with a normal crew of five men. The operating data indicated that, if desired, the volume could most readily be reduced by replacing existing water closets with those of a more efficient design.

Impoundment tank odor was controlled easily and satisfactorily by an activated carbon vent filter. The vent filter effectively controlled odor throughout the test period with an acceptable pressure drop (1/2 to 1 in. of water) during pump-out.

The impoundment tank and the transfer lines can be automatically flushed in a relatively simple and reliable manner. A momentary tap of the reset pushbutton is all that is required to initiate each automatic flush during tank pump-out. The additional convenience and flexibility of a manual override pushbutton, and permissive switches for simultaneous flushing of the drain lines along with the tank and transfer lines, were desirable features. The level sensing system, consisting of a bubble tube, a differential flow controller, and pressure gages, performed flawlessly under all operating conditions. A perforated pipe ring provided satisfactory flushing action.

Storage of solid galley waste in the specially designed trash compactor was a satisfactory and practical means of increasing galley storage capacity.

Test results showed that on the average, a two-week quantity of solid galley waste can be stored in the compactor before removing the compressed garbage in a plastic bag. Based on an observed compaction ratio of about 5.1, the amount stored is equivalent to approximately 14 cu ft of uncompacted galley waste. The unit can be operated with relative ease and safety.

General Acceptability and Applicability

The system is simple to operate and requires minimal operating attention and maintenance.

The additional gage located in the galley was convenient for monitoring the tank level at all times. Acknowledgement of the high level alarm, and arming of the automatic flush control circuitry by pressing a pushbutton, prepare the impoundment tank for pump-out. Quick-connect fittings facilitate connection to and emptying of the tank by deck-mounted or shore-based facilities.

The air motor-driven pump mounted onboard the tugboat was controlled by a manually operated globe valve. In very cold weather, "icing" of the air motor muffler necessitated its removal during pump-out. Water must also be drained from the pump after each use during the winter months.

The amount of routine maintenance required is minimal. Occasional inspection of the air line lubricators and air filters, together with changing of the pump gear oil and activated carbon about twice a year, comprise the normal maintenance schedule.

Operating costs are normally quite low, assuming pump-out facilities have been made available by the owner or are available at nominal cost. The cost of sole reliance on a septic tank pumper for regular pump-out of the impoundment tank, however, is relatively high.

The design approach is compatible with existing facilities in a large number of medium-sized commercial vessels used in coastal and harbor waters. Use of sea water flushing, dc power for control systems, corrosion resistant materials, and relatively small components, ensures widespread system applicability. Operation of the level sensing system, control valves, and sewage pump depends on the availability of compressed air. On most commercial vessels an air compressor is standard equipment; however, for those vessels without a compressed air supply, motor-operated or solenoid-operated control valves and a dc motor-driven pump could be substituted for their air-operated counterparts. In addition, an alternate level sensing concept would have to be used.

The system is compatible with various shore-side storage and transfer facilities.

Compatibility of the impoundment system with a septic tank pumper in terms of mating to the quick-connect deck fitting and efficient pumping out of the holding tank was successfully demonstrated. In the absence of suitable dockside facilities, transfer to a sewer system or package treatment plant was simulated by emptying the holding tank with a compact, inexpensive, air-motor driven diaphragm pump into a portable dockside storage tank. For purposes of this program, the pump was deck-mounted to anticipate emergencies while at sea or other ports where pump-out facilities are not available. Under normal operating conditions, a shore-based pump would have sufficed, based on an average observed pump-out interval of 3 days. Occasional excursions to other ports, however, especially with an increased crew, might well require either more widespread pump-out facilities or further reductions in the tank volume accumulation rate before a deck-mounted pump could safely be eliminated as an integral part of the system, and a completely tamper-proof system achieved.

The acceptability of transferring salt water flushed wastes from Navy barges into municipal sewers and treatment plants has been established for the City of Groton, Connecticut.(1) The relative quantities of sea water involved, according to Metcalf and Eddy, city consulting engineers, were considered negligible, and should have no detrimental effect. The holding tank capacity onboard the Three Deuces is less than one-tenth the size of the barge holding tanks referenced in the article.

The initial cost of the demonstration unit installed on the Three Deuces tugboat, as anticipated, was moderately low.

The total installed cost of the prototype waste impoundment system as installed on the Three Deuces tugboat amounted to $8,970. Approximately 65 percent of the total cost is attributable to the impoundment and transfer functions, and the remaining 35 percent to the sanitary and galley waste control systems. Cost reductions totaling $1,500 to $2,000 for large-scale production of components such as the impoundment tank and trash compactor are projected.

(1) The Day, New London, Conn., P 16, February 5, 1970

RECOMMENDATIONS

Now that the feasibility and practicability of a waste impoundment system, such as that installed onboard the Three Deuces tugboat, has been established, various means should be explored to improve its operational effectiveness and general acceptability. Recognizing that the limited availability of dockside storage and transfer facilities is an obstacle to the widespread acceptance of any impoundment system, recommendations are made below for increasing the effective tank storage capacity. The first recommendation proposes a modification to the present installation. The second describes the merits of implementing a new concept with potential advantages for cost as well as volume reductions.

1. Replacement of existing water closets with those of more efficient design should be considered.

The effectiveness of the sanitary flush control system as currently conceived could be enhanced significantly by the use of more efficient water closets which require less water for flushing. Such water closets are being introduced in this country and are designed for operation with only half as much water as the standard water closet found on most commercial vessels. The desirability of following this recommended course of action will depend upon:

   a. The nature of the relative volume contributions for a specific vessel.
   b. The additional cost of implementing such a modification as opposed to the alternate approach of increasing tank capacity through use of a more expensive form-fit receptacle.
   c. The extent of the need for further reduction in the tank volume accumulation rates for a particular vessel.

2. Use of a vacuum flush system for the transfer of sanitary wastes to an impoundment tank should be considered.

Further reductions in sanitary flush volumes can be achieved only by the use of a more efficient and conceptually novel approach to waste transfer, such as the vacuum flush system. In a system of this type, wastes are air-conveyed from specially designed water closets to a receiving tank by a vacuum pump with the use of only 1/2 gallon of water per flush. Use of such a vacuum flush system could reduce the total volume accumulation rate observed in this program from 7.5 to approximately 3.5 gallons per man-day.

A substantial fraction of the total system cost is associated with the procurement and installation of the various piping systems. Hence, the use of 2-in. lines under 15-in. Hg vacuum, as opposed to 3-in. gravity drain lines, could result in substantial cost savings. The savings are the result of the (a) reduced cost per foot of drain line, (b) relative ease of installation without the restriction of allowing for gravity drainage, and (c) elimination of the need for relocating or modifying existing structures or equipment.

An accurate assessment of the initial and operating costs associated with incorporating a vacuum flush system can only be obtained by designing, installing, and testing this type of impoundment system under actual operating conditions. Only then can a realistic appraisal be made in terms of cost, effectiveness, and acceptability.

Finally, it is recommended that replacement of the specially designed trash compactor by a mass-produced, electrically operated unit be considered if and when such units become available for domestic consumption. A unit of this type, developed by one of the major appliance manufacturers, is currently being test marketed, and should prove attractive in terms of reduced initial cost as well as increased operating convenience. The manufacturer claims the appliance will be able to compact a week's worth of garbage for an average family in a polyethylene lined bag, with a compaction ratio of 4.5:1.

SECTION 2

INTRODUCTION

For most commercial and recreational watercraft, the use of an impoundment system with disposal at a shore facility portends the highest probability of success in controlling the principal waste sources cited below. The approach is relatively simple, reliable, and well within the state of the art. In addition, the method is compatible with existing facilities in most commercial watercraft and with presently foreseeable methods for disposal of waste at shore facilities. Since there is no effluent, the system conforms to state regulatory legislation.

The goal of this program has been to demonstrate the practicability and acceptability of this approach by developing a waste storage/disposal system based on the following criteria:

a. Moderately low initial cost (equipment plus installation costs).
b. Minimal operating attention and maintenance.
c. Tamper-proof, i.e., not easily bypassed.
d. Simple to use and psychologically acceptable.
e. Components small enough to fit through hatchways and doors.
f. Odor-free.
g. Design approach applicable to a large number of watercraft.
h. Compatible with various shore disposal techniques.

Such a waste impoundment system has been designed, built, and installed by Electric Boat division on a commercial tugboat (the Three Deuces) to serve as a demonstration unit. The Three Deuces, built in 1944 for the Navy, is 115 feet long, 28 feet wide, and 15 feet deep (draft). It is powered by two 600-horsepower diesel engines, and is currently used for coastal and harbor towing. The waste impoundment system has been operationally tested and evaluated, while in use by the crew under routine working conditions, for a period of two months.

Of specific interest in this program were the sanitary (urine and feces) and galley wastes generated onboard ship. Both forms of waste are significant sources of pollution in terms of:

a. The oxygen demand of organic matter.
b. The quantity of suspended matter.
c. Pathogenic organisms.

The content of organic matter insidiously influences the dissolved oxygen content of waters receiving the waste, while the discharge of large amounts of suspended matter produces pollution obvious even to the casual observer. The potential health hazard (as indicated by coliform index) is, of course, extremely important.

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SECTION 3

SYSTEM APPROACH

OVERALL SYSTEM DESCRIPTION

The current shipboard practice of "over the side" waste disposal incorporated in present ship designs uses sea water flushing of the sanitary facilities into gravity drain lines. Similar gravity drainage is used for galley waste, with all such drain lines terminating in discharge ports at or near the waterline. The modifications required to provide for the temporary storage and subsequent shore transfer of sanitary and galley waste onboard the Three Deuces are reflected in Figure 1. This spatially oriented sketch shows the approximate location of the various components specifically designed to accomplish these modifications. Figure 2 presents the system in schematic form, and shows functional interrelationships more clearly and the degree of support provided by ship's services. For purposes of exposition, the total system can be separated into the major subsystems described below.

Impoundment Station

The overboard discharge ports are sealed and the waste lines redirected via gravity drain to a nominal 120-gallon holding tank located in a corner of the engine room. The coated steel tank is fitted with a 3-in. suction line, a level sensing system (bubble tube), an odor controlled (carbon filter) vent line, and a flush manifold. In addition, a high level alarm station and access and viewports are provided. An impoundment tank of this size will be sufficient for a minimum storage period of 2 days with a five-man crew (assuming 24 hr/day occupancy). These figures are based on incorporation of the specific volume control components described below.

Tank Flush Control System

An electronically controlled system (master control station) for the automatic flushing and cleaning of the impoundment tank, suction line, and transfer hose with a controlled quantity of sea water is incorporated in the impoundment system. Toward the end of tank pump-out, a low level sensor switches on a solenoid valve in the sea water flush line and admits sea water to the flush manifold for a preset time period. The sea water flush may be repeated as often as desired.

Sanitary Flush Control System

To provide a reasonable pump-out interval (more than 2 days) in conjunction with a relatively compact holding tank, a unique electronically controlled flush system was developed which minimizes the volume of sanitary waste. A solenoid-actuated volume control valve was installed in the existing sea water flush lines for each facility. These control valves, operated by single pushbuttons via the flush station timing and control circuitry, provide a dual flush consistent with the minimum and maximum requirements anticipated. The minimum and maximum flush volumes can be varied to suit the needs of each facility. Immediately after a flush, the corresponding valve is rendered inactive for a predetermined time period (adjustable from 0 to 5 minutes). These volume control measures are designed to produce an effective reduction in flush volume of approximately 60 to 65 percent when used with existing fixtures.

Galley Waste Control

Suitable galley sink hardware was installed to minimize waste water volume. Examination of the habits of the crew with respect to galley sink usage led to the selection of a self-closing valve, in conjunction with a single handle mixing valve, as the most efficient installation.

In addition, a specially designed trash compactor was built to facilitate storage of solid galley waste prior to shore-side disposal. The all-aluminum unit is manually operated, and can be safely handled by one man.

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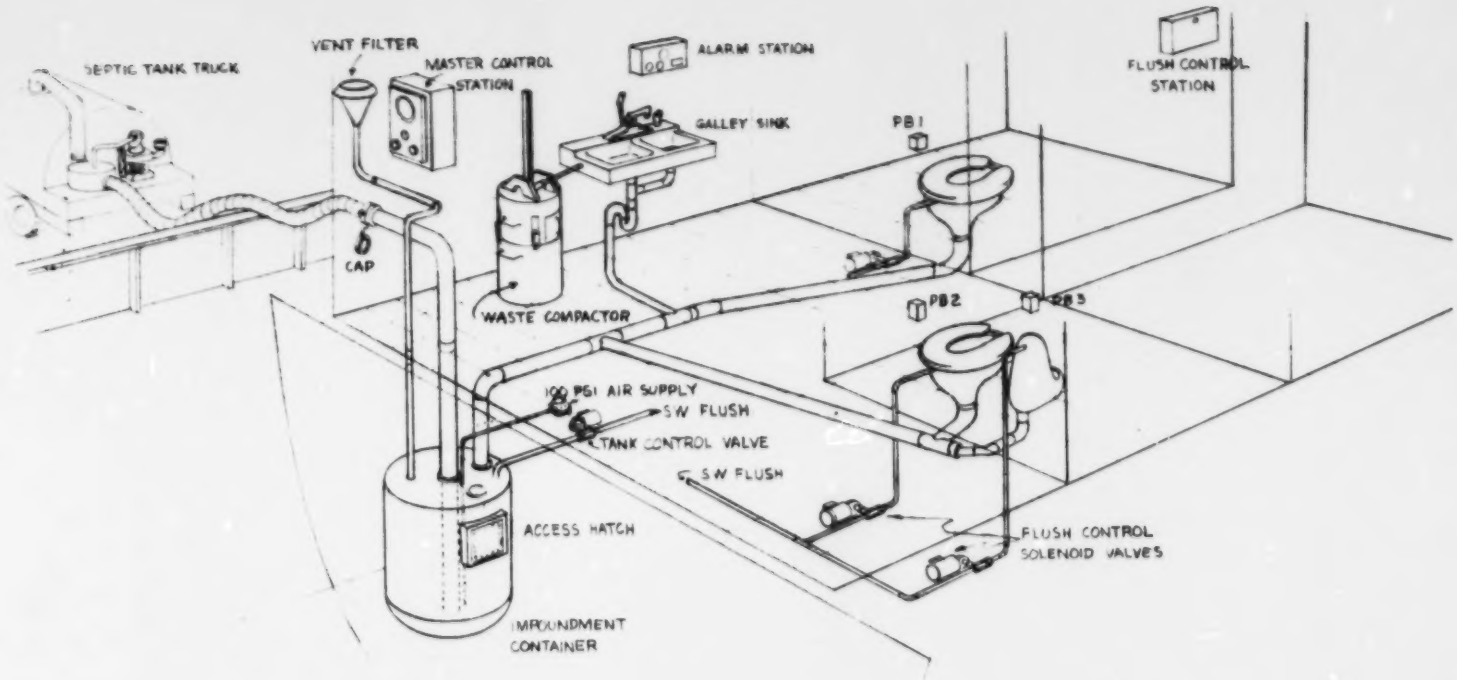

Figure 1. Watercraft Waste Impoundment System

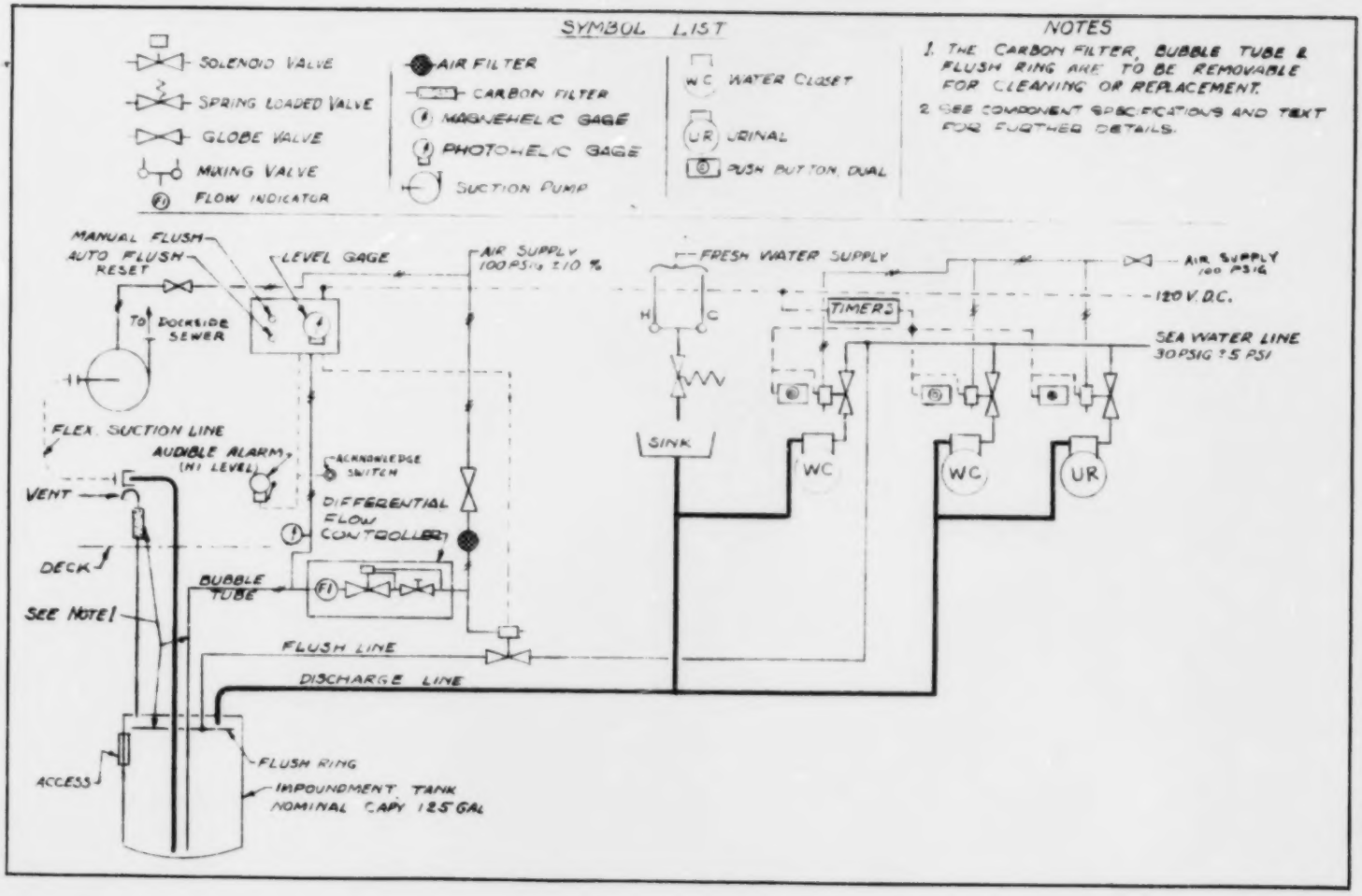

Figure 2. Waste Impoundment System – Overall Schematic

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Pump-out Station

The sanitary and galley waste stored in the impoundment tank is transferred by pumping out the tank via a quick-connect fitting mounted on the deck. A septic tank truck can normally be used to empty the impoundment tank by coupling its 100 to 150 feet of suction hose to the deck fitting. To demonstrate alternate disposal methods, a deck-mounted sewage pump with suitable suction and discharge hoses was provided. In this way, disposal into a dock-side treatment plant can also be demonstrated. In emergencies, or when the boat is at sea, overboard discharge is possible.

ALTERNATIVES TO SYSTEM APPROACH REJECTED

Alternate Flush Modes

Use of potable water, instead of sea water, for all flushing purposes was considered. Sea water flushing was selected because of the additional cost of modifying existing sea water flush facilities to use a fresh water flush, and the unlimited supply of sea water available to all boats.

Another alternative considered was the storage of used wash water and the reuse of this water for facility flushing. While this system does offer the advantage of impounding waste wash waters as well as sanitary and galley wastes at no increase in the size of the holding tank, a pump and connecting plumbing would be required. Hence, because of the increased cost and complexity of the system, this approach was not used.

Use of Compressed Air for Blow Discharge

Use of the ship's compressed air system to discharge (by displacement) the waste from the impoundment vessel was considered and rejected. This method does have the advantage of not requiring a pump or other auxiliary facility for waste discharge; however, it suffers from several disadvantages. The waste impoundment tank, connections, discharge fittings, and hose would be under internal pressures greater than 30 psig. To ensure both structural integrity and airtight seals and connections, fabrication costs of the tank would necessarily be higher than with a suction pump-out. The results of an improper connection or damaged hose would be much more unpleasant.

Additional control valves and a more complicated control system would have to be installed. Furthermore, the simple and reliable bubble tube concept used for level sensing would have to be modified or supplemented for use during tank discharge.

Finally, over-the-side disposal could be accomplished too easily.

SECTION 4

SUBSYSTEM AND COMPONENT

DESIGN, FABRICATION, AND INSTALLATION

IMPOUNDMENT STATION

Waste Impoundment Tank

A 120-gallon nominal capacity waste impoundment tank was built by Electric Boat division and installed on the Three Deuces tugboat. It was designed for the collection, temporary storage, and subsequent discharge of sanitary and galley wastes in a saline medium. Provisions were made for level sensing, and automatic flushing of the tank through a flush manifold. The tank was also equipped with an odor-controlled vent line. Details concerning these provisions are discussed below.

Figure 3 shows the detailed design of the waste impoundment tank. It has been rolled, using 3/16-in. mild steel, into a cylindrical configuration measuring 24 in. in diameter and 66 in. high. These dimensions were limited by the size of the boat's passageways and the available overhead space, respectively. A 1/2-in. steel head plate was welded to the upper end of the tank and fitted with silver brazed bronze couplings for the 1-in. vent line, 3/4-in. flush line, 1/4-in. air line, and the 3-in. drain and discharge lines. A 3-in. copper-nickel discharge pipe, located in the center of the tank, extended to within 2-1/2 in. of the bottom with a slight flare at the end. Since the suction line is an integral part of the impoundment tank, 3-in. pipe was used to virtually preclude any possibility of clogging during pump-out. A dished bottom was used to provide for a more efficient and thorough pump-out.

A 1/4-in. copper-nickel "bubble" tube, held alongside the discharge pipe by a guide ring near the bottom, forms part of the level sensing system by operating as a hydrostatic pressure probe. Approximately 2 in. below the top of the tank is a 20-in. diameter perforated pipe ring which functions as a flush manifold. Both the flush ring and bubble tube are removable through an access cover located near the top of the tank. The access hatch also permits coating of the internal surfaces after the tank head has been welded in place. The hatch has a flat, rather than contoured, cover to help ensure an airtight seal. A Plexiglas* viewport in the tank cover plate allows observation and sampling.

A two-coat (16 mils thick) application of Pitchen Tarset* was applied to all internal surfaces before installation with the exception of internal pipe unions and open couplings. This substance is a standard corrosion resistant coating normally applied to submarine sanitary tanks. A pre-installation air-leak test was also performed. An air pressure of 20 psig was applied and held for 15 minutes. No leakage or loss of pressure was observed.

To provide sufficient overhead space as well as adequate structural support, the impoundment tank was installed to rest on a steel support cradle approximately 1-1/2 feet below the engine room deck (see Figure 4). A steel belly band, secured to the hull, provide lateral stability.

Flush Manifold

The finalized design of the flush manifold appears in Figure 3. Based on a laboratory evaluation of various configurations, a perforated pipe ring was judged best able to provide a uniform and thorough flushing of the tank's interior surfaces. A perforation pattern of 1/16-in. holes on 2-in. centers angled 55 degrees upward was found to provide the most effective flushing action. Additional holes were provided to ensure adequate flushing of the access hatch, bubble tube, and discharge pipe. Under a pump pressure of 30 psig, the flush manifold can deliver 15 gpm of sea water at linear velocities of 25 fps.

*Mention of commercial products does not imply endorsement by the Federal Water Pollution Control Administration.

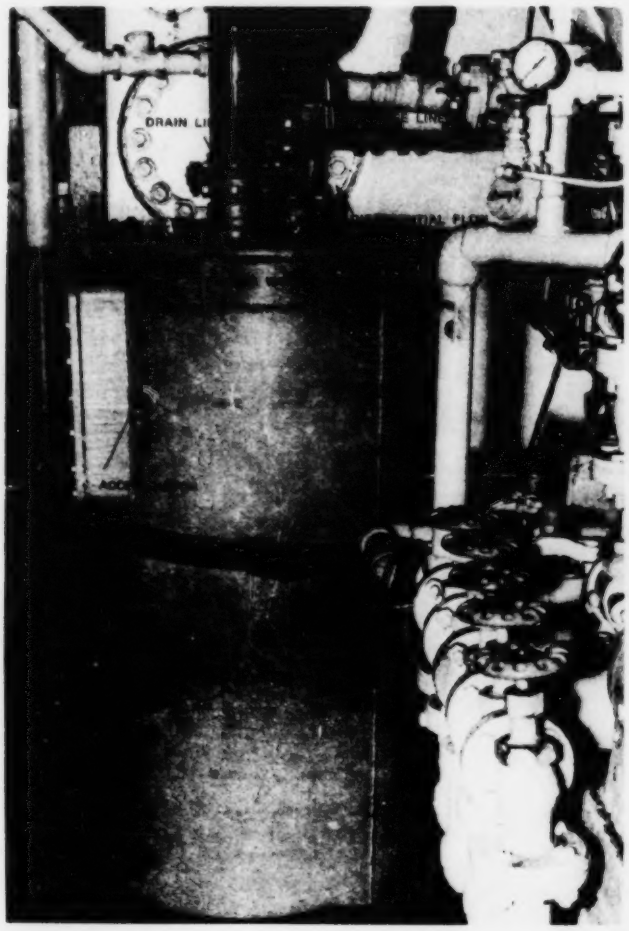


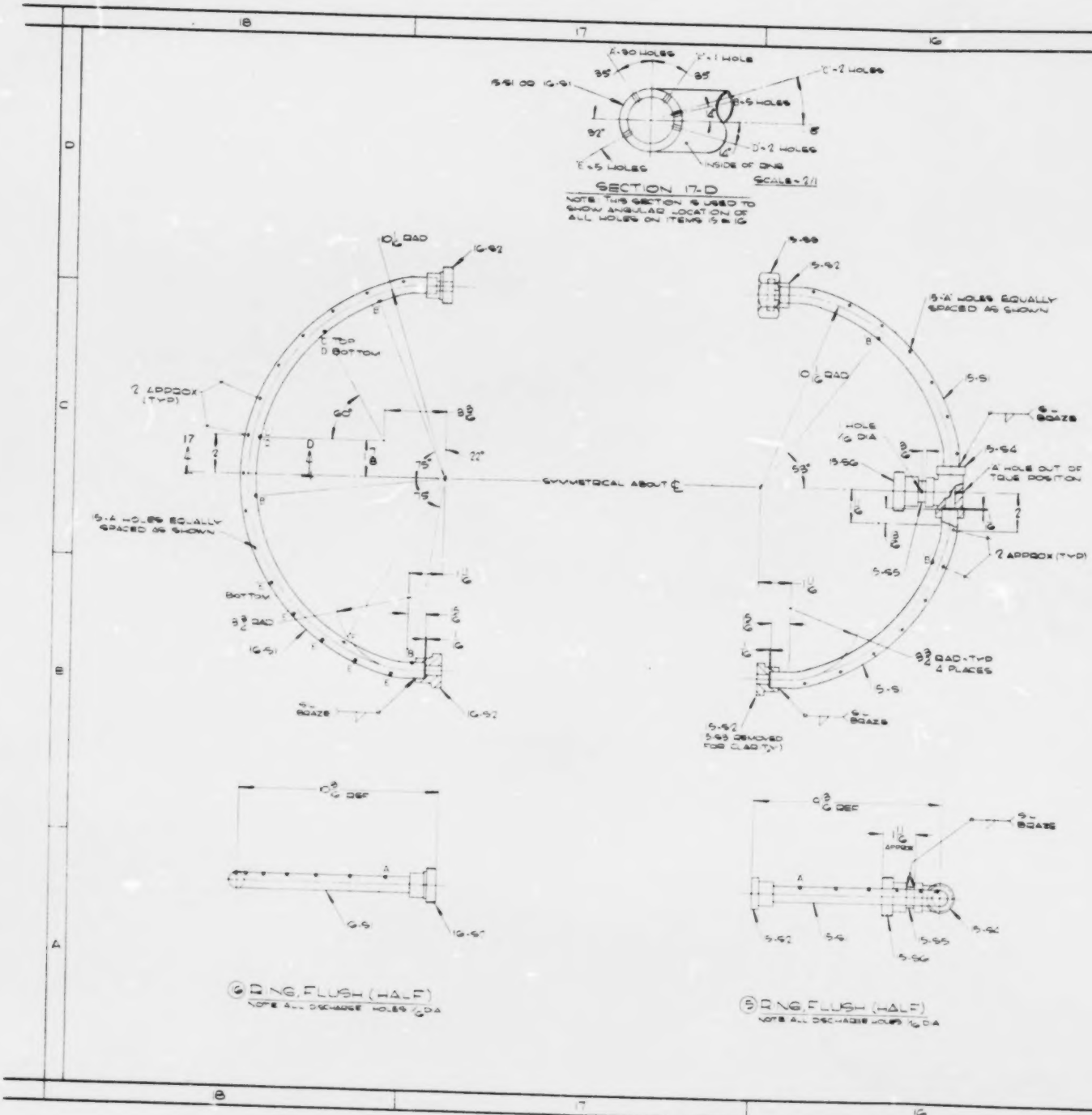
Figure 4. Waste Impoundment Tank--Installed

The 20-in. diameter flush ring consists of two 1/2-in. copper-nickel semicircular pipe sections which were coupled inside the tank by two bronze unions. A bronze tee, silver brazed into one of the sections, connects to the 3/4-in. sea water flush line through a bronze union. This fluid connection, together with a clamp fastened to the cover plate, puts the flush ring in the desired position.

Vent Filter

An activated carbon vent filter was provided for effective odor control of the 1-in. tank vent line. The funnel-shaped filter was constructed of 16 gage monel with a monel weather hood bolted to four equally spaced brackets (see Figure 5). A cloth bag filled with 5.2 lb of unimpregnated, technical grade, activated charcoal, MIL-C-17605 BuShips, simply rests inside the filter and is easily replaced. This type of activated charcoal has been used successfully by Electric Boat division for odor control of submarine sanitary tanks.

An important consideration in the design of the vent filter is the maximum pressure drop anticipated during either inflow or pump-out. If an excessive pressure drop occurs during inflow of sanitary or galley waste, when the tank level is nearing its allowable limit, the high level alarm system could be prematurely activated. Excessive pressure surges during pump-out could result in partial or complete removal of the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⑤ RING, FLUSH (HALF)

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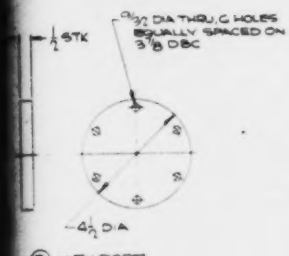
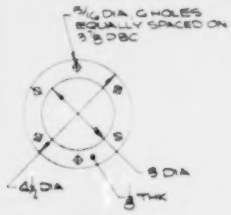


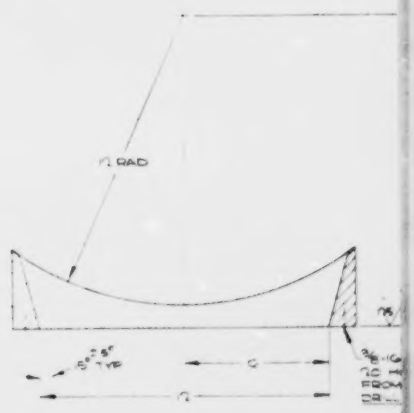
⑤ VIEWPORT



④ GASKET, VIEWPORT

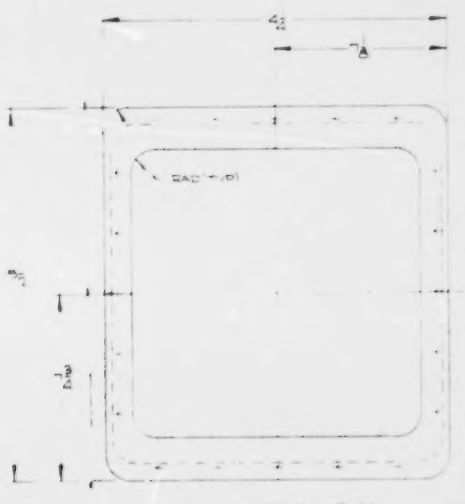
③ COVER ACCESS

DETAIL 7-5B

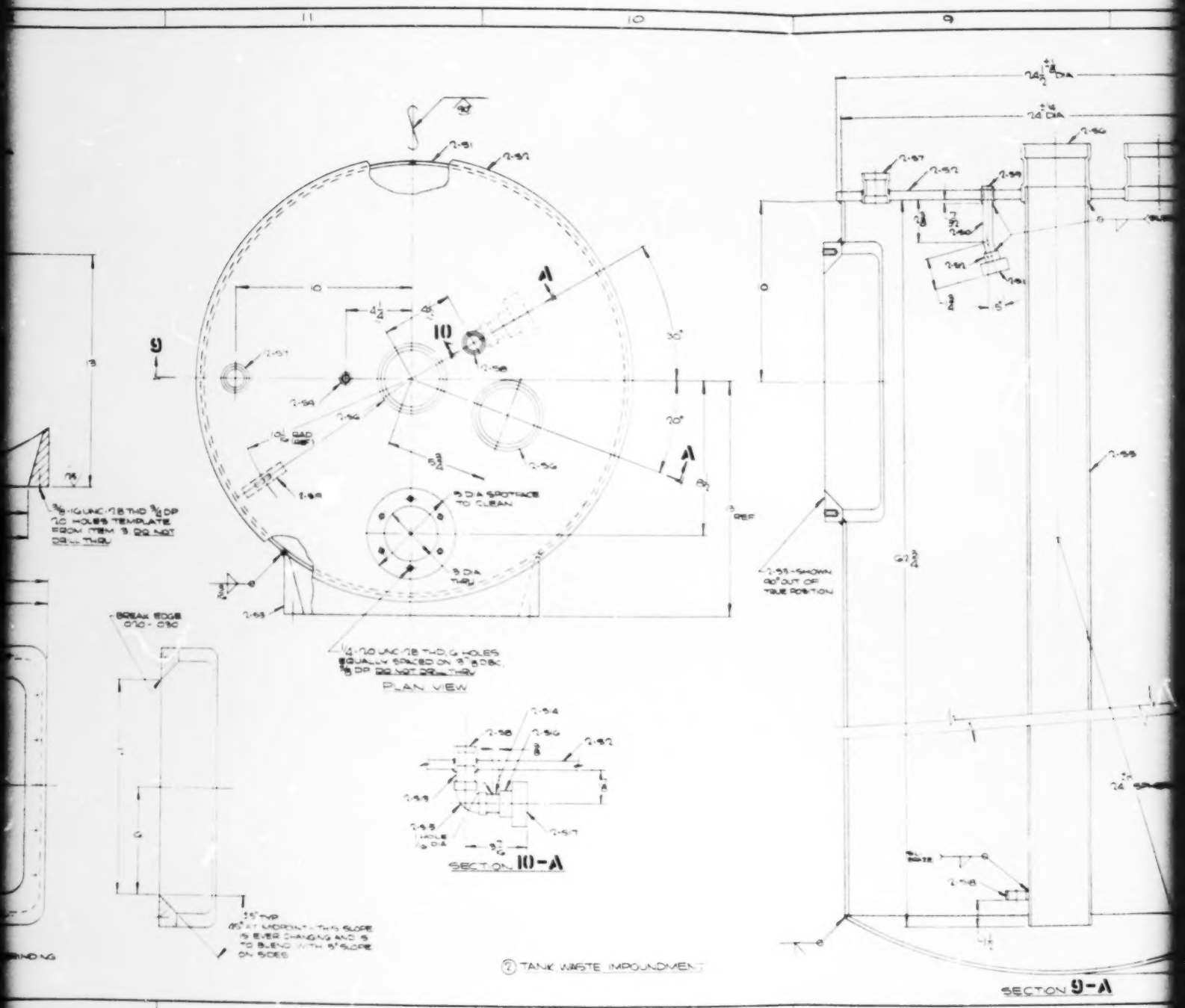


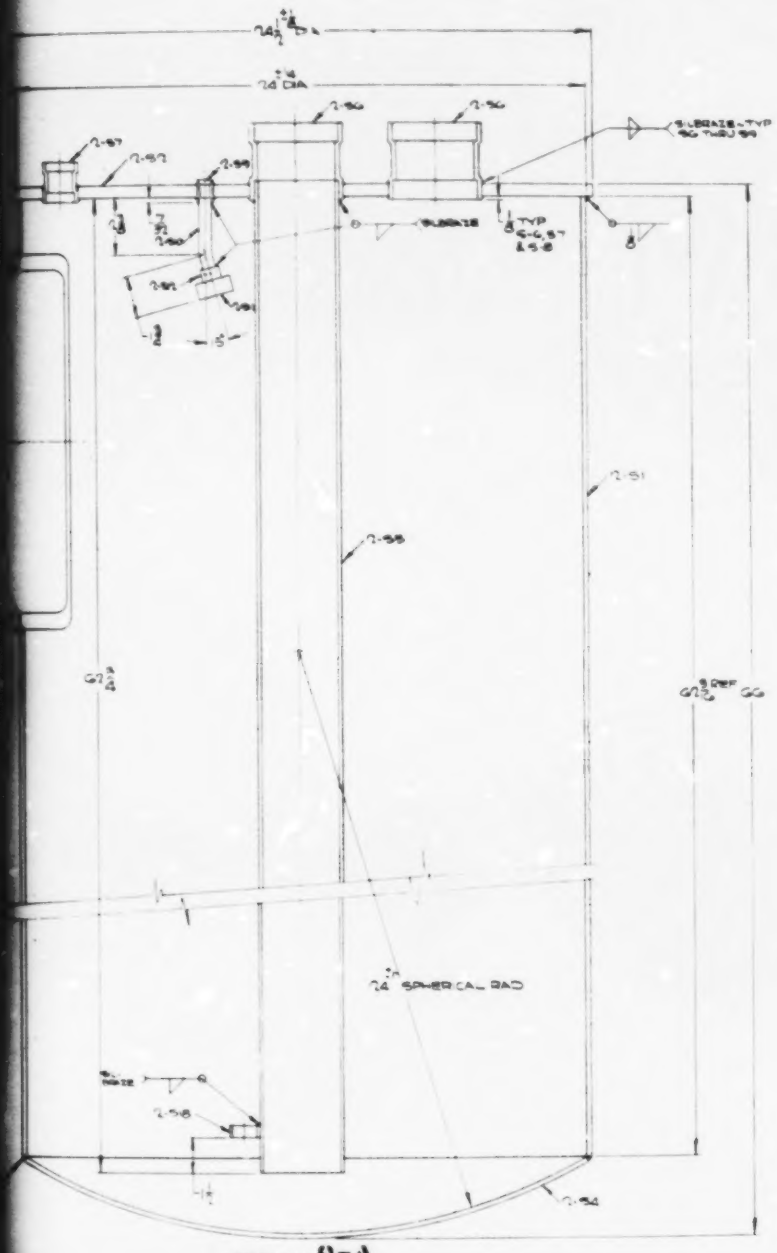
⑦ TUBE, BUBBLE

④ GASKET ACCESS COVER

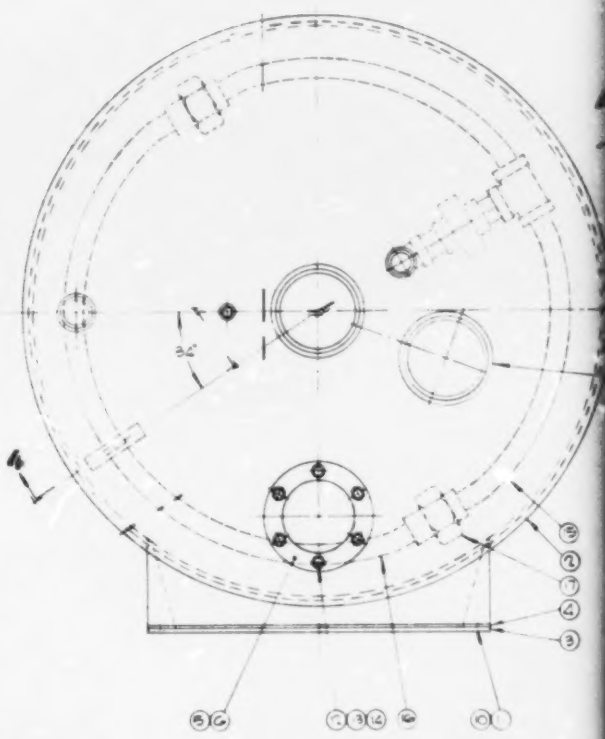


DETAIL 7-93
FLAME CUT NO. 6 HAND GRIND AS REQD


11
10
9
PLAN VIEW
SECTION 10-A
SECTION 9-A
TANK WASTE IMPOUNDMENT



SECTION 9-A



PLAN VIEW

① WASTE IMPOUND

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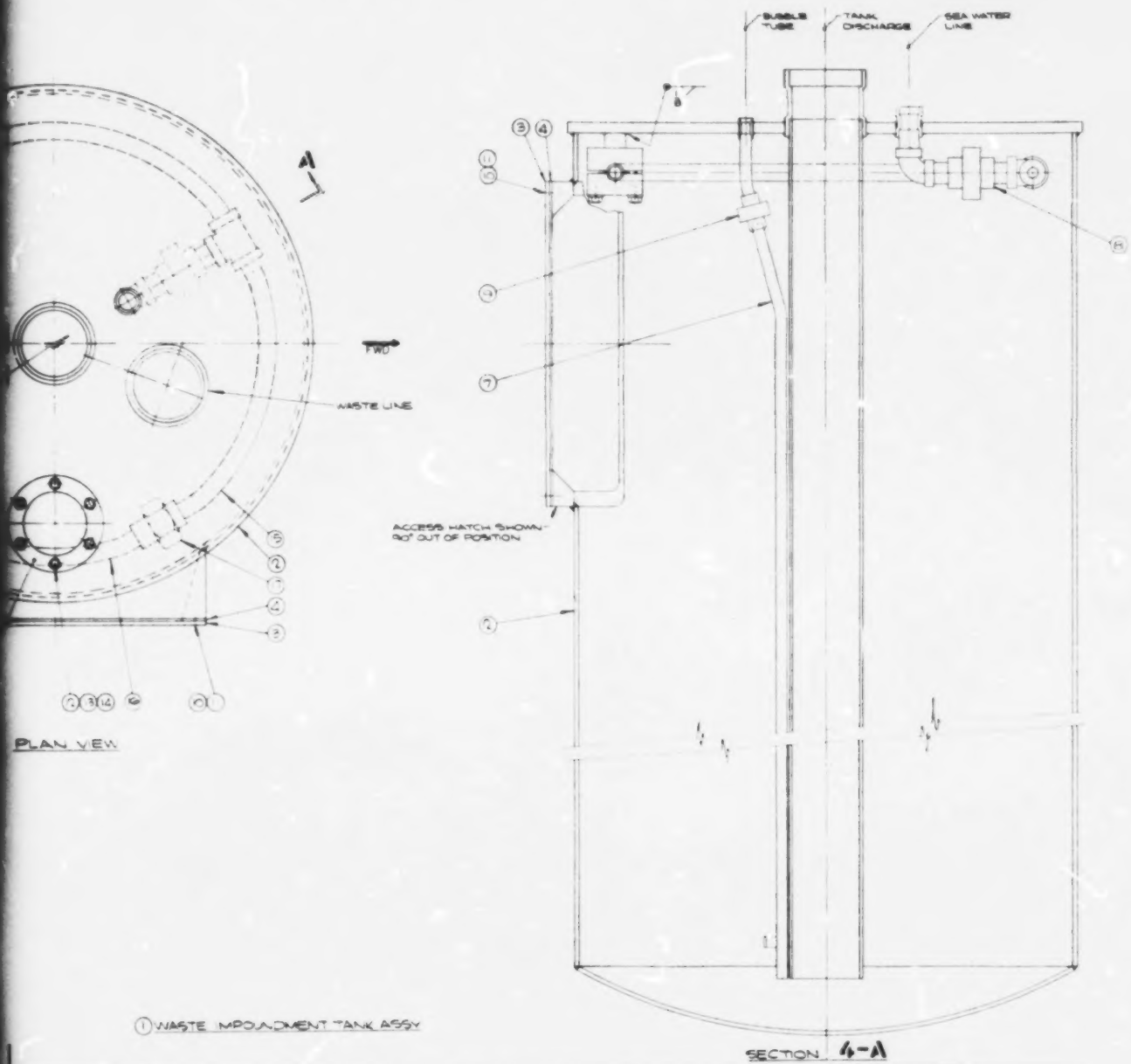
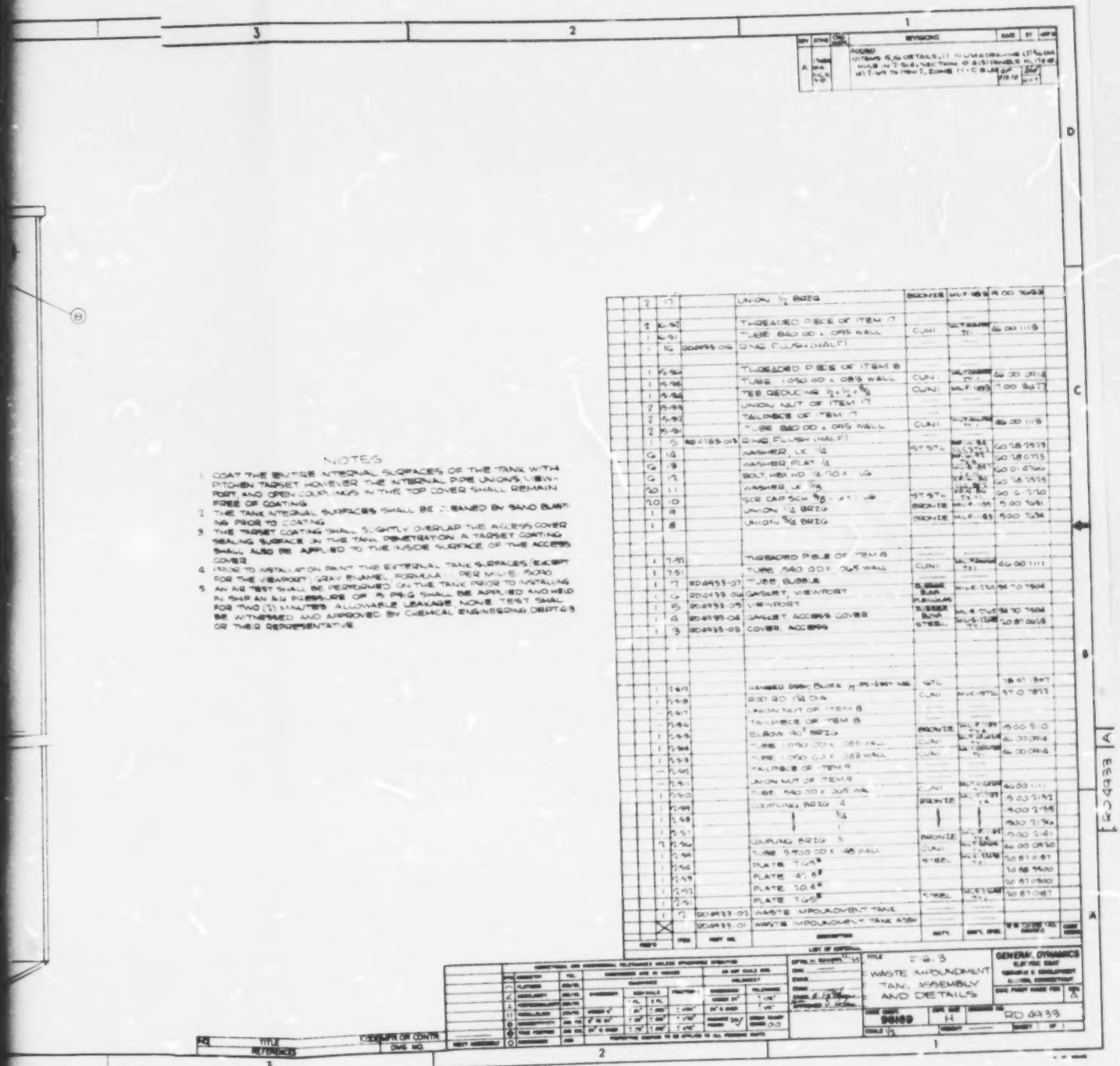
best available copy.



1. COAT THE ENTI... PITCHEN TARGET... PORT AND OPEN... FREE OF COATIN...
2. THE TANK INTER... NG PRIOR TO CO...
3. HE TARGET COA... SEALING SURFACE... SHALL ALSO BE ... COVER.
4. ...NG TO METALLI... ...ESS THE ... SURFACE...
5. AN AIR TEST SHAL... IN SHIP AN AIR PR... FOR TWO (2) MIN... BE WITNESSED ... OR THEIR DESIG...

(1) WASTE IMPOUNDMENT TANK ASSY



NOTES

1. COAT THE ENTIRE INTERNAL SURFACES OF THE TANK WITH PITCHEN TARGET HOWEVER THE INTERNAL PIPE UNIONS VIEW-PORT AND OPEN COUPLINGS IN THE TOP COVER SHALL REMAIN FREE OF COATING
2. THE TANK INTERNAL SURFACES SHALL BE CLEANED BY SAND BLAST-ING PRIOR TO COATING
3. THE TARGET COATING SHALL SLIGHTLY OVERLAP THE ACCESS COVER SEALING SURFACE ON THE TANK PENETRATION A TARGET COATING SHALL ALSO BE APPLIED TO THE INSIDE SURFACE OF THE ACCESS COVERS
4. PRIOR TO INSTALLATION PAINT THE EXTERNAL TANK SURFACES (EXCEPT FOR THE VIEWPORT) GRAY ENAMEL, FORMULA 1 PER MIL-E-7000
5. AN AIR TEST SHALL BE PERFORMED ON THE TANK PRIOR TO INSTALLING IN SHIP AN 8# PRESSURE OF 8 PSIG SHALL BE APPLIED AND HELD FOR TWO (2) MINUTES ALLOWABLE LEAKAGE NONE TEST SHALL BE WITNESSED AND APPROVED BY CHEMICAL ENGINEERING DEPT 4-8 OR THEIR REPRESENTATIVE

ITEM	QTY	PART NO.	DESCRIPTION	MATL
1	17		UNION ½ BRZG	BRONZE
2	16		THREADED PIECE OF ITEM 17	
1	15		TUBE 840 OD x .065 WALL	CUNI
1	16	RD4933-06	DWG FLUSH (HALF)	
1	9		THREADED PIECE OF ITEM 8	
1	10		TUBE 1.050 OD x .065 WALL	CUNI
1	11		TEE REDUCING ½ x ½ x ⅜	CUNI
2	12		UNION NUT OF ITEM 17	
2	13		TAILPIECE OF ITEM 17	
2	14		TUBE 840 OD x .065 WALL	CUNI
1	5	RD4933-05	RING FLUSH (HALF)	
6	14		WASHER LK ⅛	ST STL
6	13		WASHER FLAT ⅛	
6	12		BOLT HEX HD ⅛-20 x 1½	
6	11		WASHER LK ⅜	ST STL
20	10		SCR CAP SCH ⅜-16 x 1	ST STL
1	9		UNION 1¼ BRZG	BRONZE
1	8		UNION ⅜ BRZG	BRONZE
1	7A1		THREADED PIPE OF ITEM 8	
1	7B1		TUBE 840 OD x .065 WALL	CUNI
1	7	RD4933-07	TUBE BUBBLE	
1	6	RD4933-04	GASKET, VIEWPORT	SILICONE RUBBER PLENUM
1	5	RD4933-05	VIEWPORT	SILICONE RUBBER PLENUM
1	4	RD4933-04	GASKET ACCESS COVER	SILICONE RUBBER PLENUM
1	3	RD4933-03	COVER, ACCESS	STEEL
1	2A1		HANGER ASSY, PIPE (RD 4933 NO. 2)	ST'L
1	2B1		ROD RD 1¼ DIA	CUNI
1	2A1		UNION NUT OF ITEM 8	
1	2A2		TAILPIECE OF ITEM 8	
1	2A3		ELBOW 90° BRZG	BRONZE
1	2A4		TUBE 1.050 OD x .065 WALL	CUNI
1	2A5		TUBE 1.050 OD x .065 WALL	CUNI
1	2A6		TAILPIECE OF ITEM 9	
1	2A7		UNION NUT OF ITEM 9	
1	2A8		TEE 840 OD x .065 WALL	CUNI
1	2A9		COUPLING BRZG 4	BRONZE
1	2A10		COUPLING BRZG ¾	BRONZE
1	2A11		COUPLING BRZG 1	BRONZE
3	2A12		TUBE 9.400 OD x .065 WALL	CUNI
1	2A13		PLATE 7.06	STEEL
1	2A14		PLATE 4.75	
1	2A15		PLATE 10.45	
1	2A16		PLATE 7.06	STEEL
1	1	RD4933-01	WASTE IMPOUNDMENT TANK	
		RD4933-01	WASTE IMPOUNDMENT TANK ASSY	

REVISIONS			
REV	ZONE	DESCRIPTION	DATE
A		ADDED ITEMS 6,16 DETAILS (1) & (2) ON SHEET 2, SECTION C-C & (3) ON SHEET 3, SECTION C-C & ITEM 17 ON SHEET 1, ZONE 11-C	

TITLE: WASTE IMPOUNDMENT TANK ASSEMBLY AND DETAILS

GENERAL DYNAMICS ELECTRIC BOAT

SIZE: D | CODE IDENT NO: 80100 | DWG NO: RD 4933 | REV: A

SCALE: ½ | WEIGHT: | SHEET 1 OF 1

REFERENCES | TITLE | COMPUTER OR CONTR DWG NO.

RD4933 A

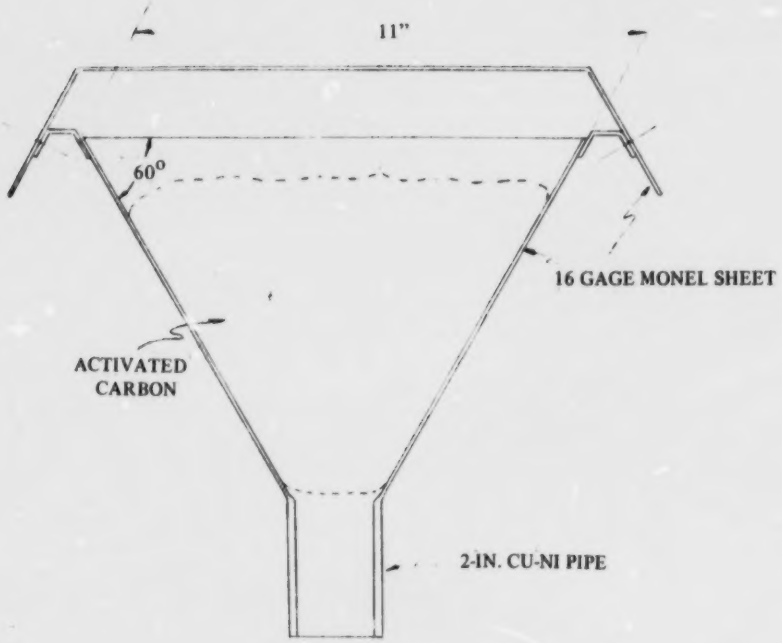


Figure 5. Vent Filter

sanitary facility and galley sink water traps. Accordingly, the filter size and configuration were selected so as to limit the pressure drop to 0.6 in. of water for air flow rates up to 10 cfm. If necessary, the pressure through the carbon bed can be decreased significantly by inserting a suitable support at any desired level.

The vent filter is coupled, through a 2-in. bronze union and reducer, to the 1-in. vent line about 10 feet above the deck, and is readily accessible from the top of the deck house.

IMPOUNDMENT STATION CONTROL SYSTEM

A sophisticated and versatile electronic monitoring and control system was developed to provide:

a. Continuous monitoring of the liquid level inside the waste impoundment tank.

b. Controlled automatic flushing of the impoundment tank during pump-out.

c. High level alarm (audible and visual) and overflow protection.

Figure 6 presents in schematic form the interactions of the primary components and subsystems which comprise the sanitary and tank flush control systems. Those items associated with the impoundment station are the level sensing system components, master control station, solenoid flush valve, and the alarm station. The precise nature of their operation, and a detailed description of the control system circuitry and logic, are presented in the following paragraphs.

Level Sensing System

The liquid level inside the waste impoundment tank is continuously monitored by means of a level sensing system based on the use of a hydrostatic pressure probe commonly referred to as a bubble tube. A bubble tube is a simple and reliable device for balancing air pressure against head of liquid in a vessel for remote level sensing (see Figure 3).

This system uses the ship's air compressor as a source of pressurized air. The compressed air is first passed through a filter and then through a differential flow controller (adjustable from 0 to 2.5 cfh) before entering the bubble tube. The flow controller maintains a constant flow of air through the bubble tube which is independent of changes in upstream and downstream pressure. The controlled single bubble formation at the bottom of the tube ensures equivalence of air pressure in the tube and head of liquid in the tank. The back pressure in the bubble tube is sensed and indicated at two places: a magnehelic gage mounted in the alarm station, and a photohelic pressure switch/gage mounted in the master control station.

Master Control Station and Alarm Station

The master control station, mounted on the after, port side of the deck house, is the operator's control station for flushing of the impoundment tank. This station houses the timing circuit for the impoundment tank flush valve, printed circuit board for low level control and high level alarm, photohelic gage, and switching for the selection of either or all of the sanitary flush valves to operate in unison with the tank flush valve. The power supply for the photohelic indicator relay is located in a separate enclosure to preclude excessive heat buildup within the master control station.

The physical layout of the master control station is shown in Figures 7 and 8. Manual controls include:

a. Manual override pushbutton located underneath chassis.

b. Reset pushbutton located on cover.

c. High and low set point indices located on the photohelic gage.

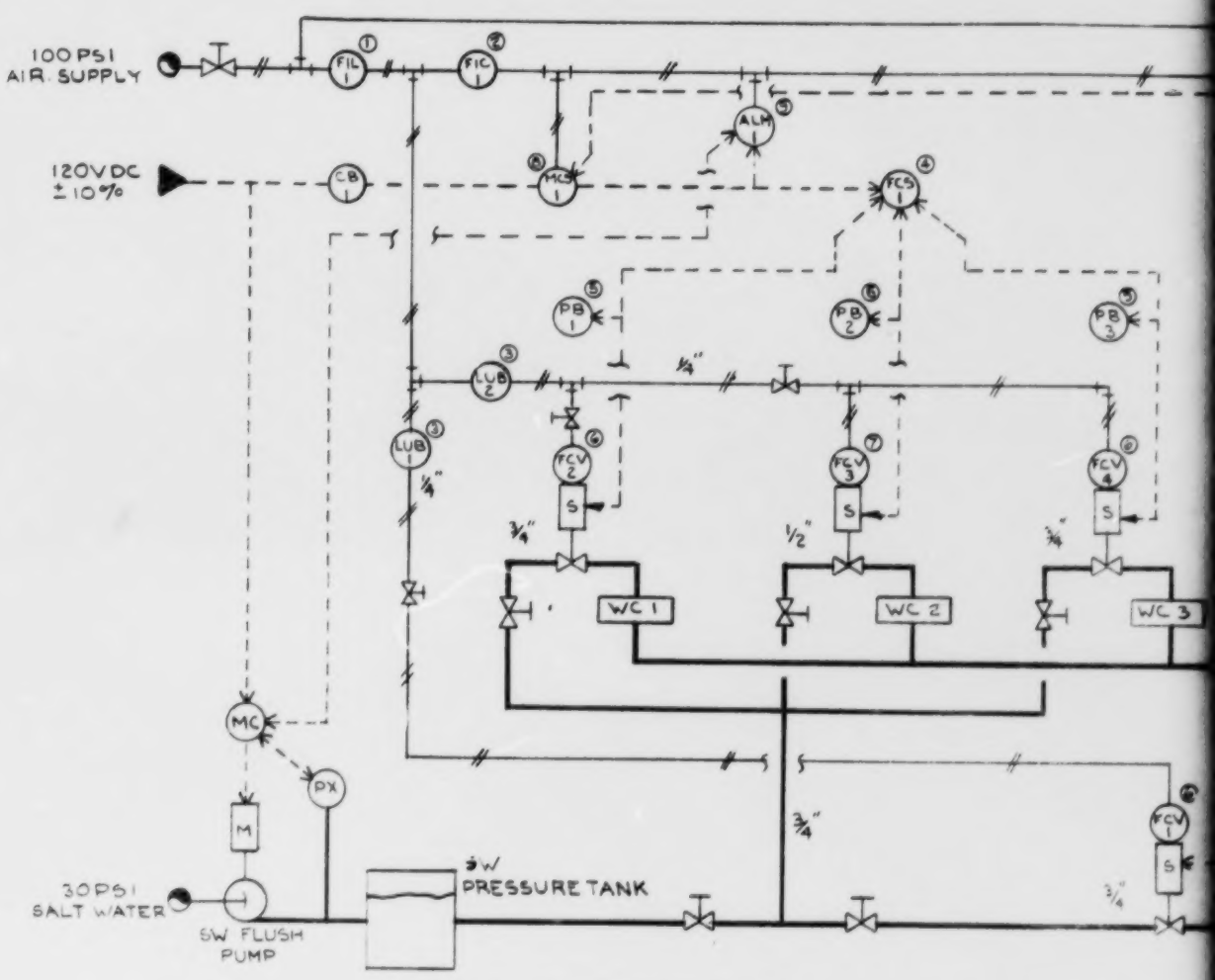
d. Permissive switches for allowing each flush station valve to operate in unison with the holding tank flush valve.

e. Time duration of holding tank flush valve, adjustable from 3 to 300 seconds.

The high level alarm station mounted above the galley sink houses a bell, acknowledge pushbutton, high level red light, alarm relay, and tank level indicator (see Figure 9).

The operation of both the master control station and the alarm station is best illustrated by means of a timing diagram (see Figure 10) showing the sequential operation of the various control station elements in each operational mode. The circuitry that was developed to accomplish each operation and the corresponding terminal board connections are to be found in Figure 11. The printed circuit board which contains the photocell switching circuitry is shown in Figure 12. Operation of the system requires that all ship's services be available and energized, e.g., 120(±10 percent) volts dc, 100 psi air, and 30 (±5) psi salt water.

Over the normal operating range, i.e., between the low and high level set points, the photohelic gage's photocell beam is on and the resistance of the photocell resistors (PSC LL/PSC HL) is low. When the tank level indicator exceeds the high level set point, the photobeam is cut off and the PSC HL resistance suddenly increases. The resultant shift in circuit voltages triggers the high level relay, CR 2, and sounds the alarm bell. Pushing the acknowledge button silences the alarm and energizes the red light on the cover. The red light remains energized by an alarm relay until the level in the holding tank is reduced below the high level set point.



SYMBOL	NAME
PX	PRESSURE SWITCH
MC	MOTOR CONTROLLER
ALM	ALARM INDICATOR
CB	CIRCUIT BREAKER
FCS	FLUSH CONTROL STATION
FCV	FLUSH CONTROL VALVE
FIC	FLOW INDICATOR CONTROLLER
FLT	FILTER
LUB	LUBRICATOR
MCS	MASTER CONTROL STATION
PB	PUSH BUTTON FLUSH STATION
S	SOLENOID VALVE
WC	WATER CLOSET

LEGEND

——— SALT WATER LINE

—#—#— AIR LINE

- - - - - ELECTRICAL LINE

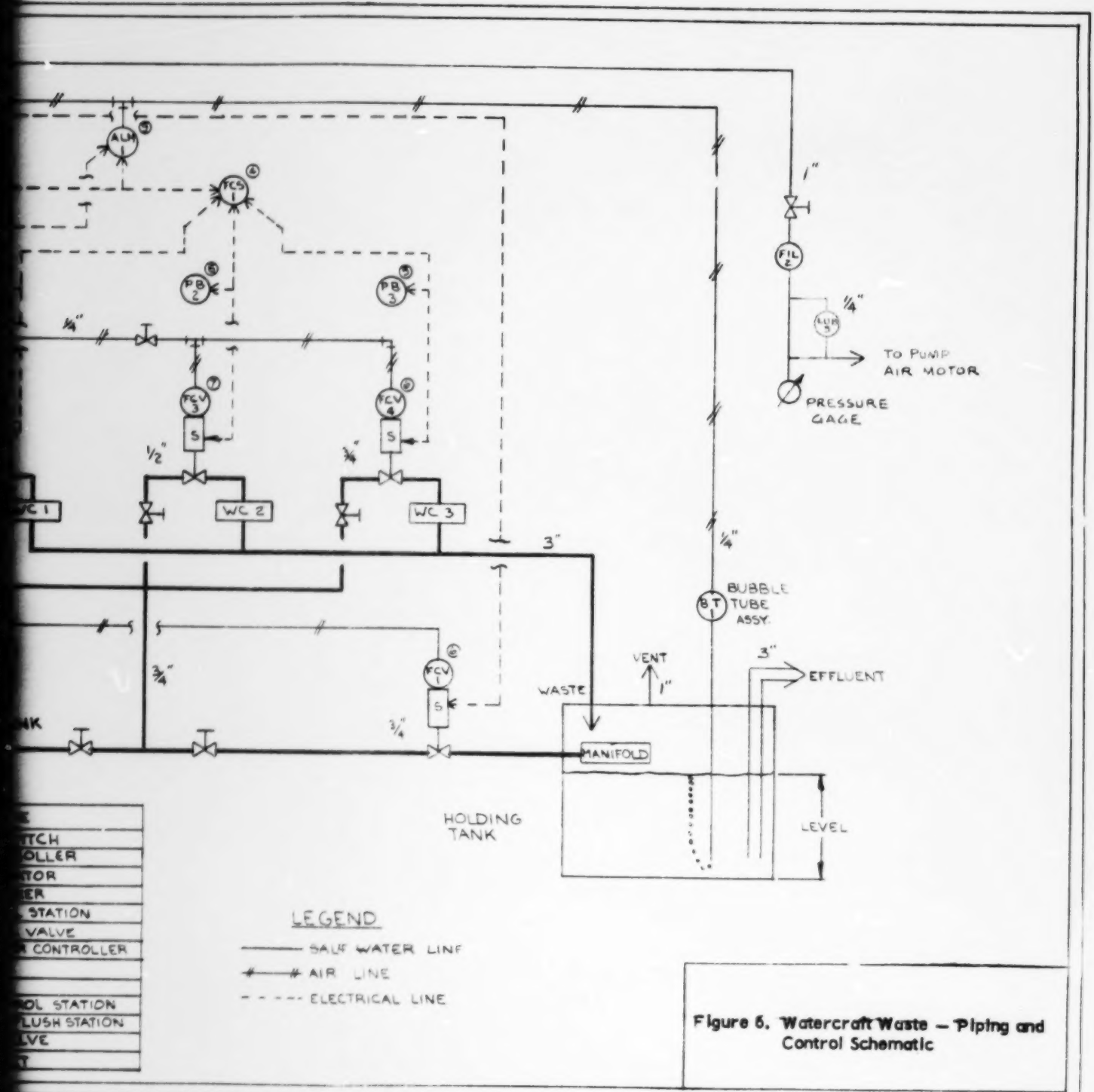


Figure 6. Watercraft Waste – Piping and Control Schematic

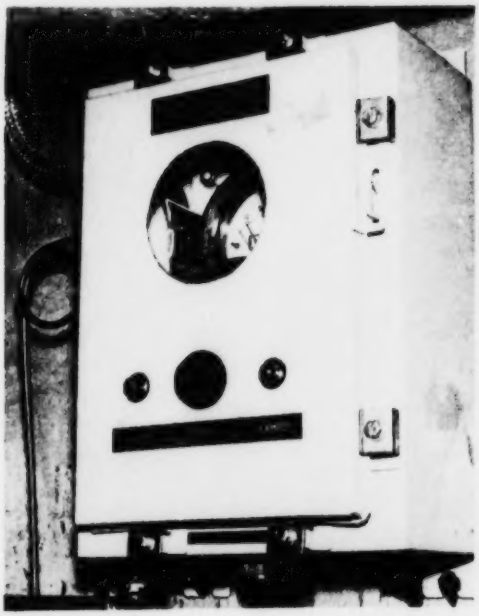


Figure 7. Master Control Station – Front Panel

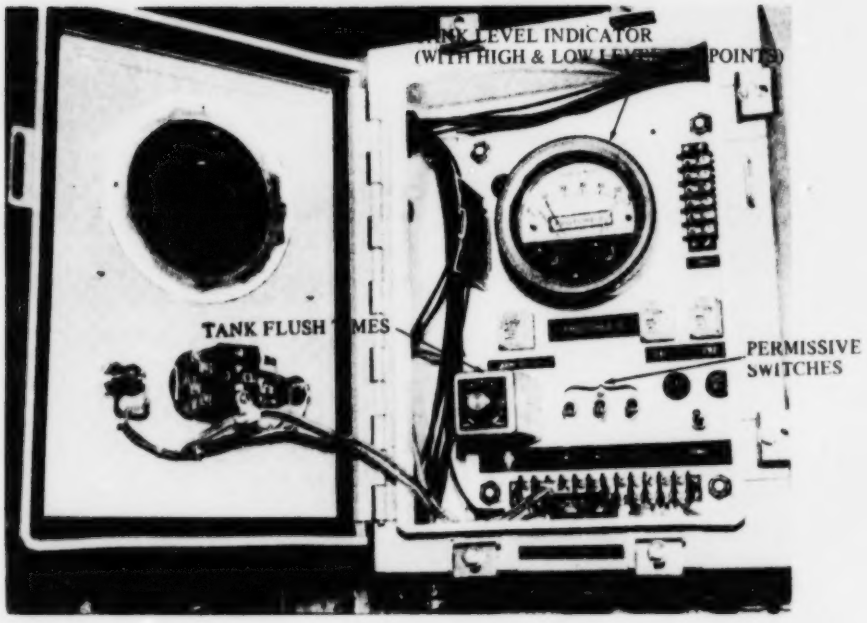


Figure 8. Master Control Station – Inside Panel

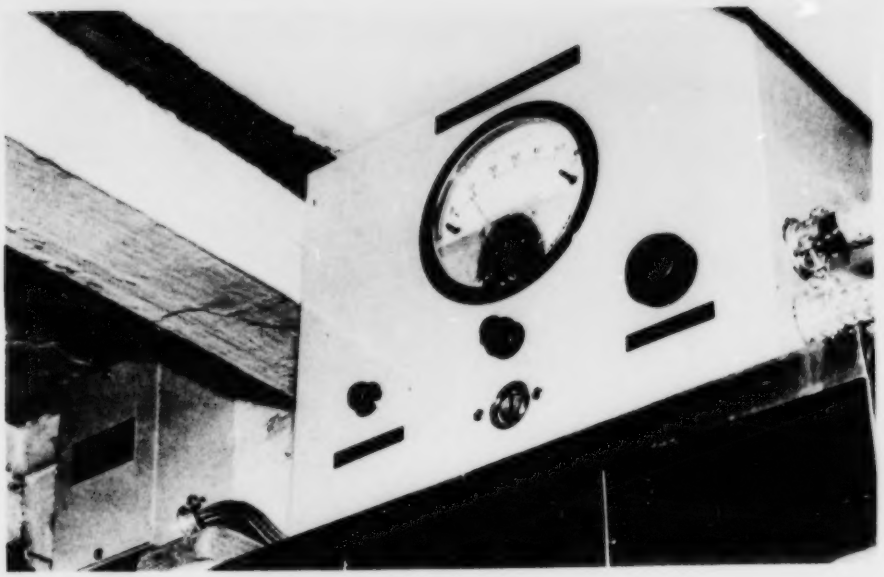


Figure 9. Alarm Station

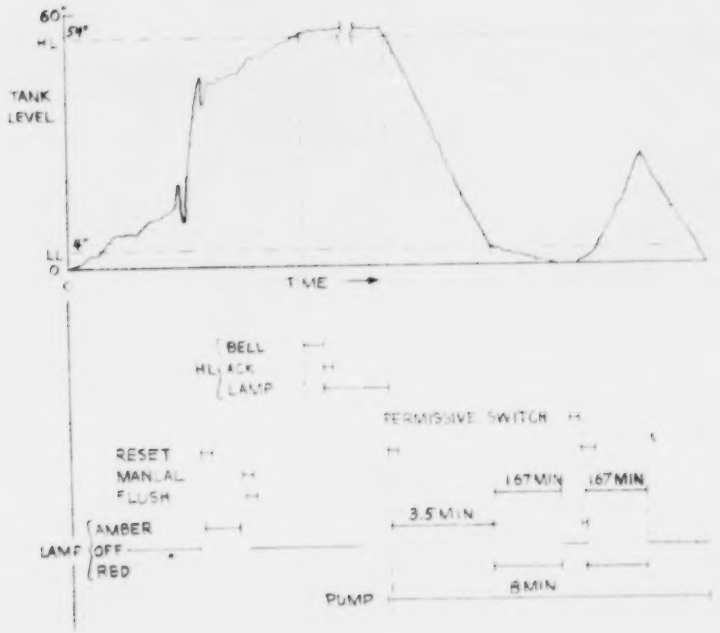
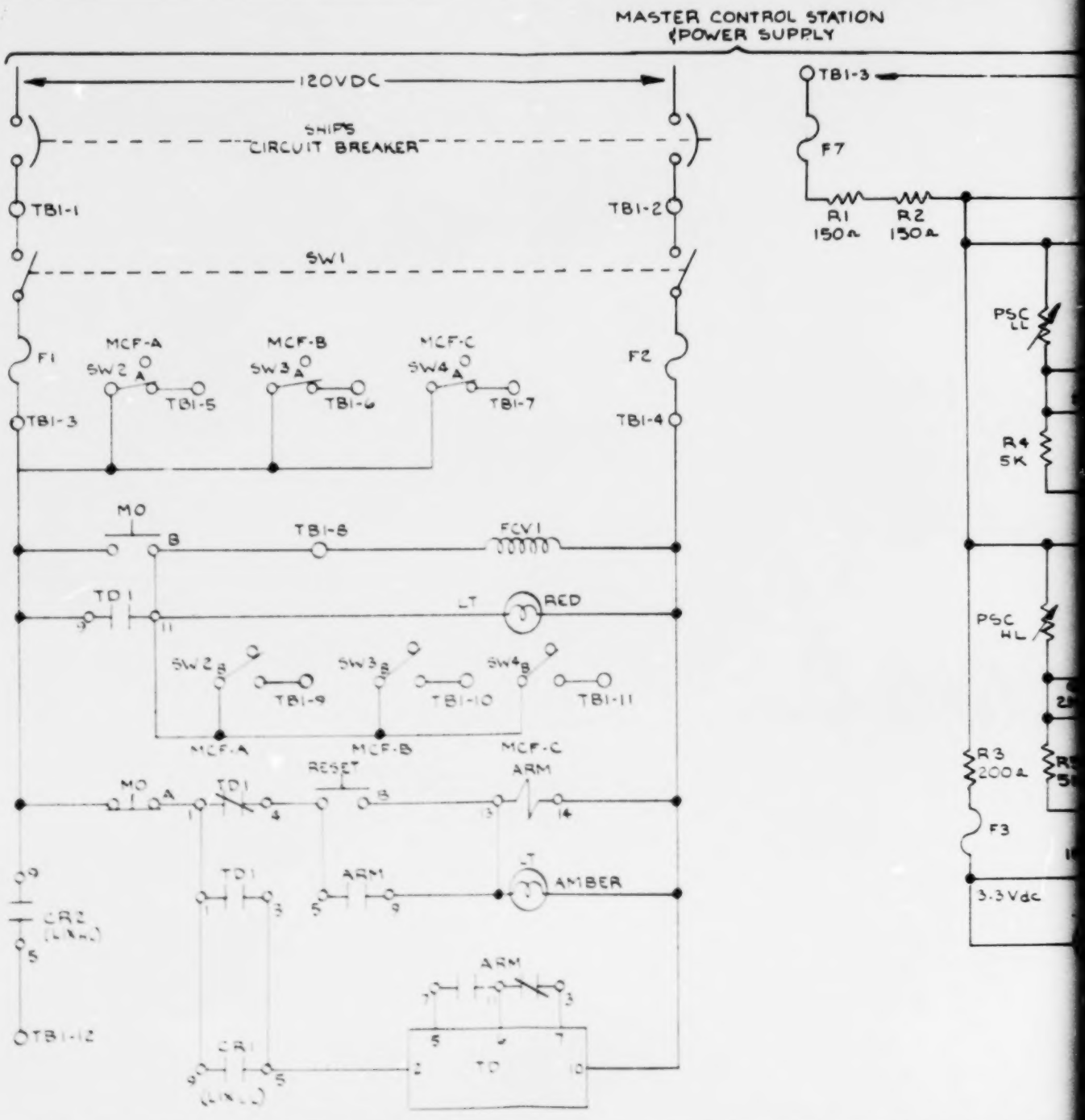
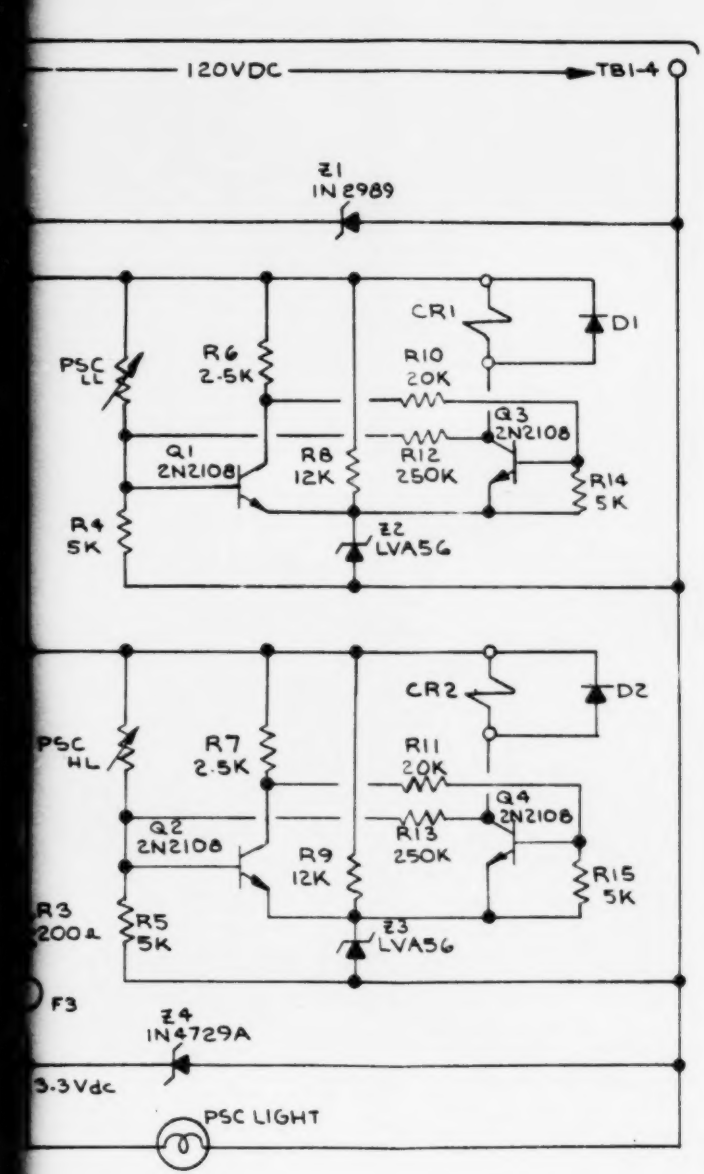
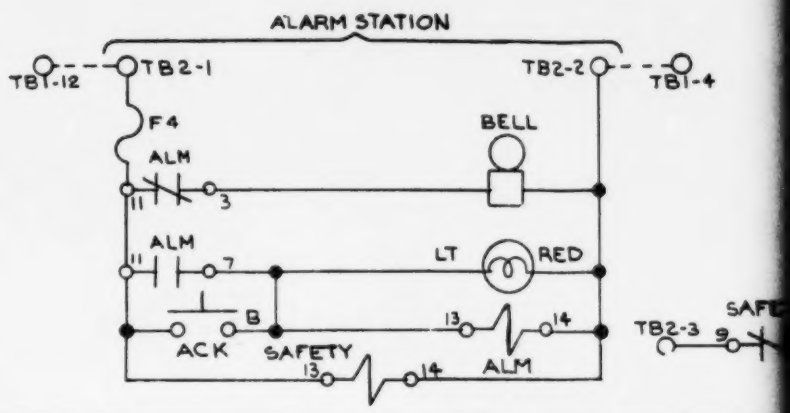
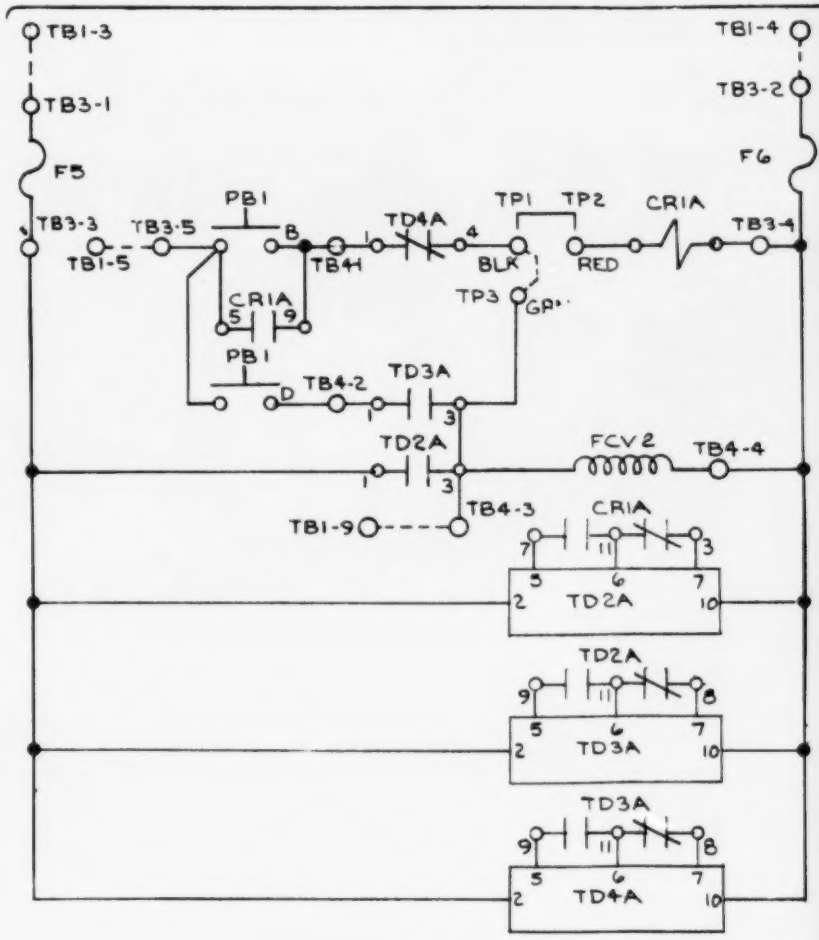


Figure 10. Timing Diagram: Master Control Station, Alarm Station


MASTER CONTROL STATION
POWER SUPPLY
120VDC
SHIPS
CIRCUIT BREAKER
TB1-1
TB1-2
SW1
F1
F2
MCF-A
MCF-B
MCF-C
SW2 A
SW3 A
SW4 A
TB1-5
TB1-6
TB1-7
TB1-3
TB1-4
MO
B
TB1-8
FCV1
TD1
LT
RED
SW2 B
SW3 B
SW4 B
TB1-9
TB1-10
TB1-11
MCF-A
MCF-B
MCF-C
RESET
ARM
MO
A
TD1
B
TD1
ARM
AMBER
CR2
TB1-12
ARM
CR1
TD
TB1-3
F7
R1
150Ω
R2
150Ω
PSC
LL
R4
5K
PSC
HL
R3
200Ω
F3
3.3Vdc


120VDC
TB1-4
Z1
IN2989
PSC
LL
R6
2.5K
CR1
D1
R10
20K
Q3
2N2108
Q1
2N2108
R8
12K
R12
250K
R14
5K
R4
5K
Z2
LVA56
CR2
D2
PSC
HL
R7
2.5K
R11
20K
Q4
2N2108
Q2
2N2108
R9
12K
R13
250K
R15
5K
R3
200Ω
R5
5K
Z3
LVA56
F3
Z4
IN4729A
3.3Vdc
PSC LIGHT


ALARM STATION
TB1-12
TB2-1
TB2-2
TB1-4
F4
BELL
ALM
11
3
ALM
11
7
LT
RED
B
ACK
SAFETY
13
14
13
14
ALM
TB2-3
9


TB1-3
TB1-4
TB3-1
TB3-2
F5
F6
PB1
TP1
TP2
CR1A
TB3-3
TB3-5
B
TD4A
4
TB3-4
TB1-5
TB4-1
BLK
RED
TP3
GR
CR1A
5
9
PB1
D
TB4-2
TD3A
1
3
TD2A
FCV2
TB4-4
1
3
TB1-9
TB4-3
CR1A
7
11
3
5
6
7
2
TD2A
10
TD2A
9
11
8
5
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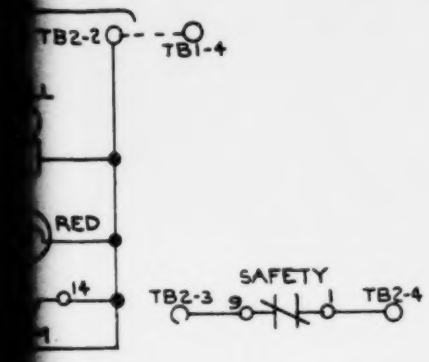
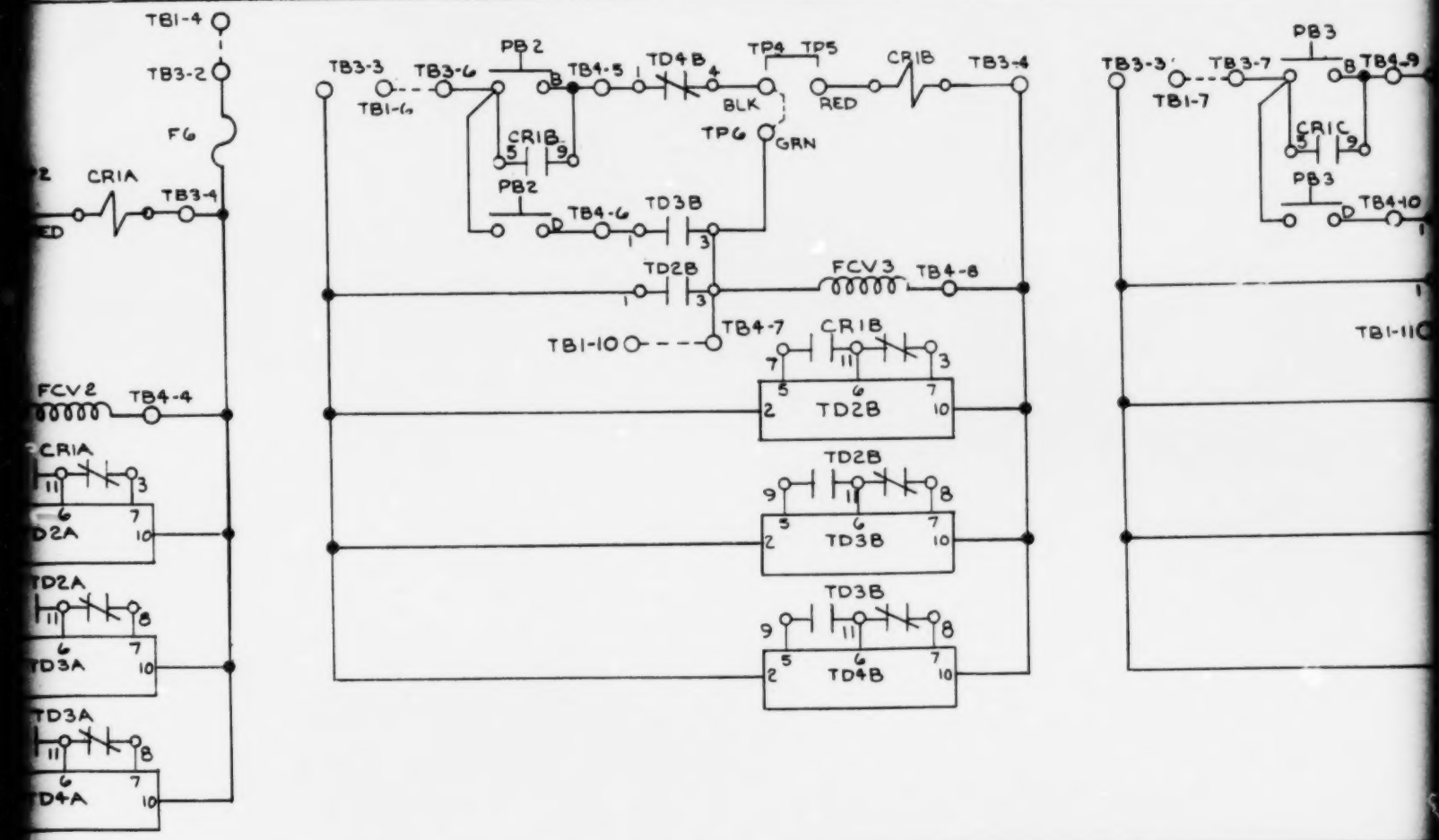
TD3A
10
TD3A
9
11
8
5
6
7
2
TD4A
10



FLUSH STATION



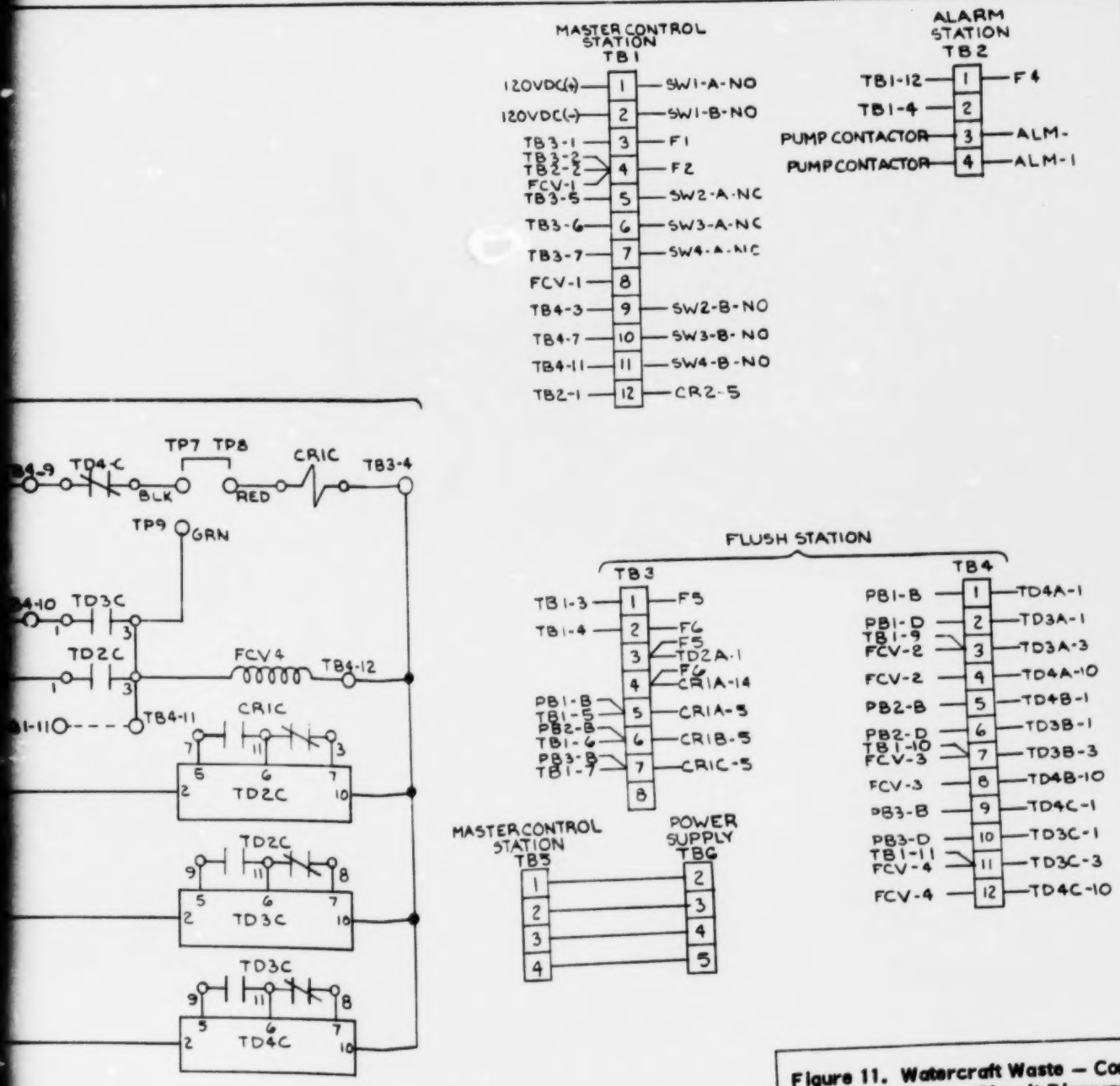


Figure 11. Watercraft Waste — Control System Circuit Diagram

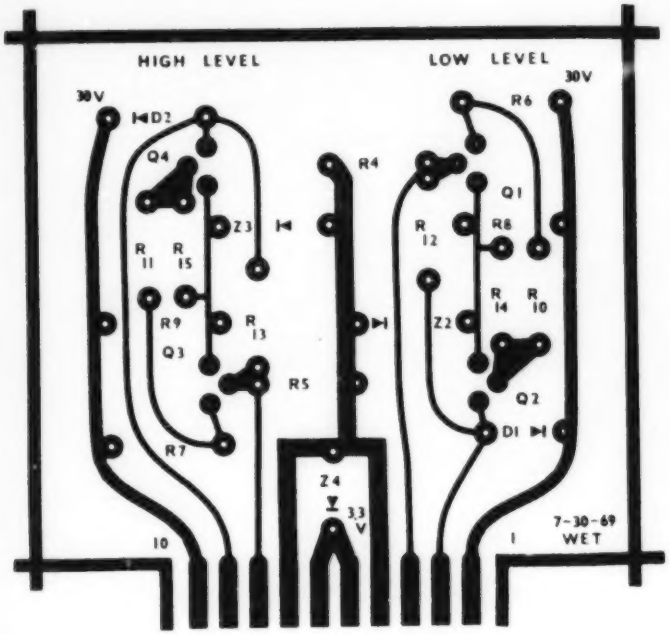


Figure 12. Photohelic Switching Circuitry – Printed Circuit Board Etching

The high level relay, CR 2, is also used to interrupt power to a motor contactor holding coil. This holding coil controls the ship's salt water flush pump which supplies the 30 psi pressure for flushing. This circuit is a safety feature designed to prevent the pump from causing an overflow if a component malfunctions. Under normal conditions, the next step in the sequence of operations is to push the reset button and pump out the tank. Pushing the reset button energizes the arming relay which, in turn, energizes an amber light. When the tank level indicator crosses the low level set point, the low level relay, CR 1, is energized, causing the arming relay to drop out and a timed flush (adjustable from 3 to 300 seconds) to start. At this time the amber light is de-energized and a red light comes on for the duration of the flush. At the end of the timing interval, the arming relay is de-energized and the signal to the flush control valve interrupted. The flush valve will not operate again until the reset button is depressed and the tank level indicator falls below the low level set point.

The system can be de-armed at any time by a momentary tap of the manual override pushbutton. In addition, the manual override will cause the tank flush valve to open for as long as the button is held in.

Activation of any or all of the permissive switches transfers control from the sanitary flush control system to the master control station, and permits a simultaneous flush of the tank and each sanitary facility and drain line.

Impoundment Tank Flush control Valve

A solenoid-energized pneumatic-actuated ball valve was selected as the tank flush control valve on the basis of minimum cost and maximum reliability and flexibility. The control valve assembly chosen consists

of three separate units (see Figure 13):

a. Jamesbury 3/4-in. "double seal" bronze ball valve, type A 11-71TT, with monel trim and Teflon seat*.

b. Jamesbury pneumatic operator, type ST-10*.

c. ASCO four-way solenoid pilot valve, type 8345A5*.

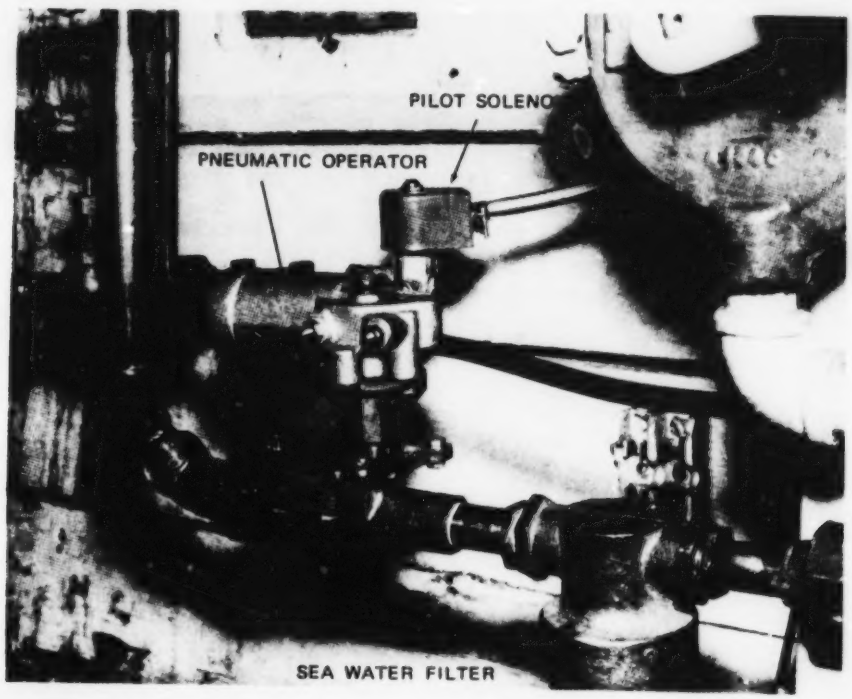


Figure 13. Tank Flush Control Valve

These items can be either supplied as integral units or purchased separately for field installation. The valve sizing coefficient, C_V, is 14. Hence the pressure drop through the valve during the automatic tank flush (15 gpm) is only about 1 psi. The pneumatic operator will actuate the 3/4-in. ball valve with a minimum supply pressure of 60 psi.

The solenoid pilot valve is furnished as fail-safe closed. Although the ST-10 pneumatic operator is a double-acting unit, the probability of air pressure failing with the valve in the open position is extremely remote.

*Mention of commercial products does not imply endorsement by the Federal Water Pollution Control Administration.

Component Specifications for Impoundment Station Control System

QTY	DESCRIPTION	SOURCE *
1	Air Filter, 1/4 in., Type 2306	Moore Products Co.
1	Air Line Lubricator, 1/4 in., No. 4102	Kennett Corp.
1	Constant Differential Relay with Rotameter, Type 62 VA	Moore Products Co.
1	Magnehelic Pressure Gage, Model 2069	Dwyer Mfg. Co.
1	Photohelic Pressure Gage/Switch, Model 3060-LRT (OEM)	Dwyer Mfg. Co.
1	Panel Enclosure, 16 x 12 x 6 in., No. A-16H12A, NEMA 4, with 13 x 7-in. Panel	Tower-Olschan Electric Supply Co.
1	Panel Enclosure, 12 x 10 x 6 in., No. A-12N106, NEMA 1, with 10 1/4 x 8 1/4-in. Panel	Tower-Olschan Electric Supply Co.
1	Time Delay Relay, Type 428-3-D-7, 3-300 sec.	Artisan Electronics
1	Zener Diode, Type 1N4729A, 3.3 v, Low, 5%	Motorola
1	Zener Diode, Type 1N2989, 30 v	Motorola
2	Zener Diode, Type LVA56A, 5.6 v	Thomas Ramo Wooldridge
3	Momentary Contact Pushbutton Switch, Flush Head Type	United Electric Supply Co.
3	110 VDC Relay, Type KHP17D11, 4 PDT	Potter & Brumfield
1	Adaptabell, 125 VDC, No. 343-4	Edwards Co.
2	24 VDC Relay, Type KHP17D11, 4 PDT	Potter & Brumfield

SANITARY FLUSH CONTROL SYSTEM

A flush control system was developed which reduces both the volume and frequency of urinal and water closet flushing. It is designed for use with existing salt water flushing facilities, and requires only the replacement of existing flush valves with appropriate volume control valves to:

a. Provide a dual flush capability for each water closet consistent with the needs of the operator.

b. Render each flush valve inactive for a period of several minutes immediately after its use.

Preliminary, pre-installation testing indicated the following quantities to be adequate for satisfactory flushing:

a. Urinal – 1 pint to 1 quart per flush.

b. Water Closet – 2 gallons per flush for urine
4 gallons per flush for feces.

The actual flush quantities required for each facility were determined during flush valve calibration, and are presented in Table 1 of Section 5.

Volume Control Valves

The results of an investigation of commercially available, manually operated flush valves indicated the necessity of using remotely controlled valve operators to perform the aforementioned functions. Motor-operated Sloan* naval flush valves were considered for the job, but were not used because:

*Mention of commercial products does not imply endorsement by the Federal Water Pollution Control Administration.

a. Motor operators are supplied with ac motors only, whereas dc power only is available onboard the tugboat. Hence, a dc/ac converter would be required.

b. Minimum flush volumes exceed that desired for urinal flushing.

c. Two flush valves, with two separate pushbutton stations, would be required for each water closet, resulting in an increase in control system cost and complexity. In addition, the "short flush" pushbutton could be bypassed too easily.

In the absence of any completely satisfactory commercially available flush valve, the Jamesbury solenoid-energized, pneumatic-actuated control valve described in the preceding subsection was selected. Two 3/4-in. valves were chosen to service the two water closets, and one 1/2-in. valve for the urinal. These valves possess the following advantages:

a. A single control valve, in conjunction with a single pushbutton, to effect a dual flush operation. (The use of a single pushbutton is advantageous for minimizing indiscriminate use of the "long" flush.)

b. Compatibility with onboard dc power supply.

c. Flexibility of flush volume delivery in terms of meeting the needs of a specific fixture (urinal or water closet), the operator, or the system as a whole (unison flush).

Since the selected valve is air-operated, it can readily be adapted to provide for both adequate flushing action during siphoning and proper filling of the water trap. The corresponding modifications are illustrated in Figure 14. In the appropriate air line connection between the pilot solenoid and valve operator, a needle valve and ball check valve have been inserted in parallel. When the solenoid is energized, air flow is unimpeded through the check valve, and the ball valve opens instantaneously. When the solenoid is de-energized, the exhausted air (100 psi) is forced to go through an adjustable restriction, and a delayed closing action occurs. For reasons of esthetics, space limitations, and ease of installation, all three valves were installed beneath the main deck in the engine room overhead space.

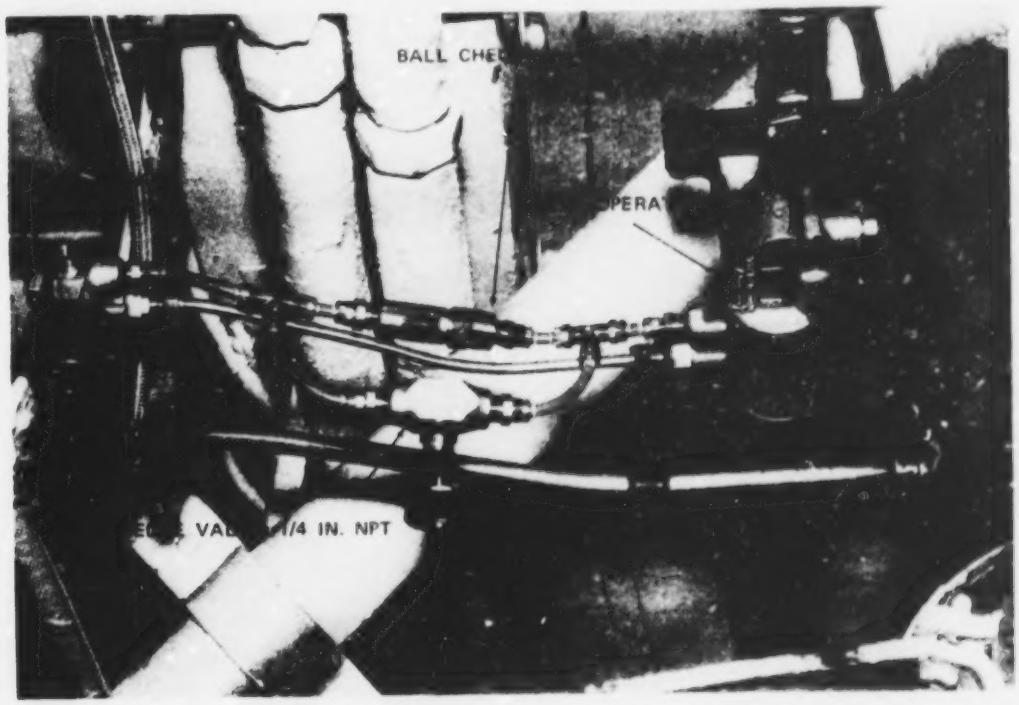


Figure 14. Modified Flush Control Valve

Flush Control Station

The flush station houses the relays, timers, and jumpers required for the timing circuitry associated with each of the three flush valves. It was mounted in a centralized, easily accessible location alongside the engine room stairway. The physical arrangement of the flush control timers can be seen in Figure 15.

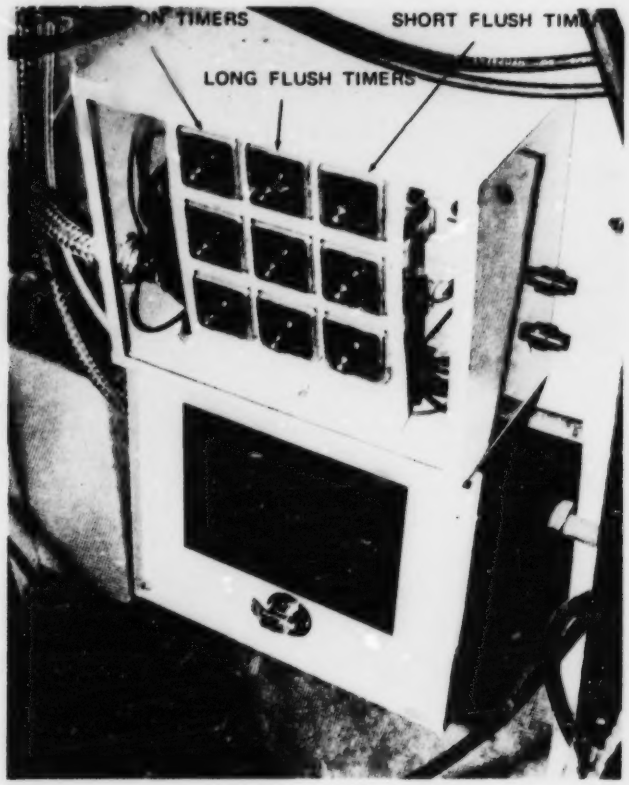


Figure 15. Sanitary Flush Control Station

The timing circuitry is identical for all three flush valves (see Figure 11). Each flush station circuit consists of three timers and an arming relay. The three timers are required to give:

a. An initial (short) flush time, variable from 0.5 to 10 seconds, for a momentary closure of the pushbutton.

b. A secondary flush time, variable from 0.5 to 10 seconds, for as long as the pushbutton is held closed. Hence the combined (long) flush time can vary from 1.0 to 20 seconds.

c. A flush valve de-activation time, variable from 3.0 to 300 seconds, for a length of time determined by the setting of the third timer.

The only other time these valves can be energized would be through the master control station with the permissive switch in the ON position.

The dual flush and de-activation capability described above is effected as follows:

Case 1. A momentary closure of the pushbutton energizes relay CRIA which maintains circuit closure by holding contacts CRIA 5 through 9 closed, and also arms relay contacts at timer TA2A. This action, in turn, energizes an internal relay which sequentially arms relay contacts associated with timers TD3A and TD4A. The arming of timer TD4A opens contacts 1 through 4, thereby de-energizing relay CRIA and initiating time delay on dropout of timer TD2A. During this time period (0.5 to 10 sec), the flush control valve pilot solenoid is energized until TD2A times out.

Case 2. Upon de-energizing of the TD2A timing circuitry, the TD3A arming relay is de-activated and the second timer is set into motion (0.5 to 10 sec). During this time period, energizing of the valve solenoid can occur only by sustained closure of the pushbutton.

Case 3. When TD3A times out, timer TD4A is activated (3 to 300 sec). The pushbutton is now incapable of energizing the control valve solenoid as all of the corresponding circuit contacts are open. When TD4A de-energizes, the arming circuitry returns to normal, and the timing circuit is capable of initiating another controlled flush.

Component Specifications for Sanitary Flush Control System

QTY	DESCRIPTION	SOURCE*
1	Enclosure, No. A12N106 NEMA 1 12 x 10 x 6 in., with 10 1/4 x 8 1/4-in. Panel	Tower-Olschan Electric Supply Co.
6	Time Delay Relay, Type 428xD7S, 0.1 to 10 sec.	Artisan Electronics
3	Time Delay Relay, Type 4283D7, 3 to 300 sec.	Artisan Electronics
3	Momentary Contact Pushbutton Switch, Flush Head, Type 3NO-3NC	United Electric Supply Co.
3	110 VDC Relay, Type KHP 17D11, 4PDT	Potter & Bromfield
2	Hoke Bell Check Valves, 1/4 in. NPT, Type 6113F4B	J. Bertram Co.
2	Hoke Needle Valves, 1/4 in. NPT, Type 2RBZ81-1^{O}	J. Bertram Co.

GALLEY WASTE CONTROL

Solid Waste Compactor

An all-aluminum trash compactor (see Figure 16) was provided to reduce solid galley waste storage requirements so as to facilitate shore-side disposal and thereby minimize the incidence of over-the-side dumping. The design of the compactor is based on manual operation of a modified, ratchet-type auto jack rated at 4,000 lb capacity. The jack provides sufficient pressure to an attached bearing plate to effect a 5:1 reduction in volume of typical galley waste.

Figure 17 is an assembly and detail drawing of the trash compactor as fabricated for the Three Deuces. A standard 2-ton Sears Roebuck auto jack* with 0 to 31-in. lift, was adapted as shown in the drawing. The normally fixed portion is clamped in place by two aluminum caps to the top of the inner cylinder. The bottom of the jack stem is pinned and leaded in place to a 1-1/8 in. aluminum compressor plate which travels up and down inside the cylinder assembly. The cylinder assembly rests inside an outer can, with a disposable plastic bag separating the two cylinders. The outer can is designed to hold up to 3 ft^3 of compacted garbage. Four camloc latches, rated at 1500 lb each, hold the cylinder to the can as pressure is applied downward through the jack bearing plate to the solid waste.

The trash compactor is installed in a storage closet adjacent to the after end of the galley. To permit one man to handle the unit safety, a counterweight, attached to the jack stem via two pulleys and cables, was provided.

*Mention of commercial products does not imply endorsement by the Federal Water Pollution Control Administration.

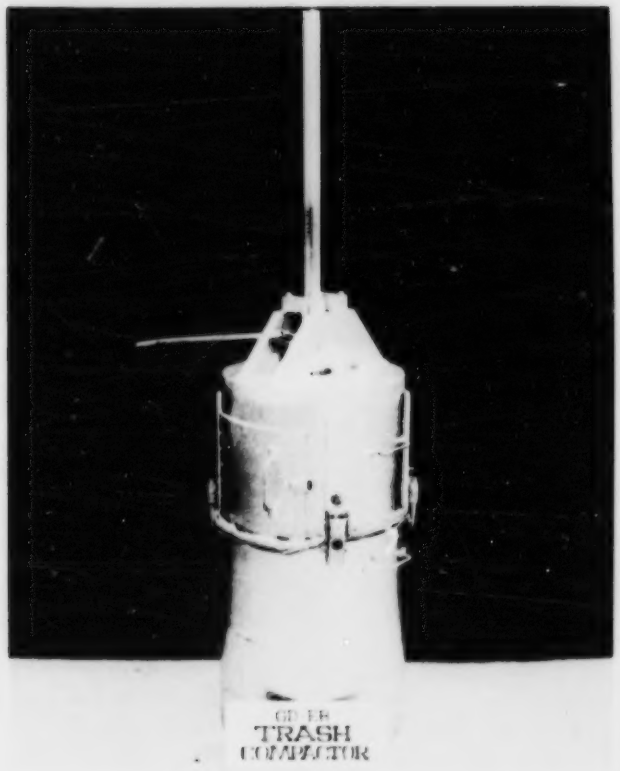


Figure 16. Trash Compactor

Operating Procedure

1. With cylinder assembly elevated and clear of the trash can, slip plastic bag with circular cardboard insert at bottom onto cylinder. Secure latches in the up position with the aid of the button magnets provided.
2. Lower cylinder into outer can and fasten latches to strikes on can.
3. Elevate bearing plate to its topmost position and secure jack stem with locking pin. Engage ratchet by placing rod in horizontal position.
4. When trash can is full, close door, remove locking pin, and begin downward jacking action. Continue compaction until limiting pressure is reached.
5. Disengage ratchet mechanism, and back off several notches on jack stem, if necessary. Raise bearing plate to its topmost position, secure with locking pin, and engage ratchet.
6. Repeat steps 4 and 5 as required until trash can is filled with compacted waste. If desired, a liquid spray disinfectant may be applied to the galley waste prior to compaction.
7. Unlatch cylinder assembly and remove locking pin. Extract cylinder by downward jacking action as far as possible, before completely removing it from trash can. Remove plastic bag and seal open end prior to dockside disposal.

Galley Sink Faucet Control

To minimize water usage in the galley, the original faucet was replaced by a single lever faucet with a hose and spray attachment. The swinging spout was sealed so that the faucet could be operated through the self-closing spray attachment only, thereby eliminating unnecessary water usage. Additional water savings accrue from the somewhat reduced flow rate (1.5 to 2.0 gpm), and the convenience of a single handle mixing valve.

PUMP-OUT STATION

The waste impoundment tank is designed for suction pump-out by either a shore-based (septic tank service truck, etc.) or deck-mounted pumping station. The 3-in. Cu-Ni suction pipe in the center of the tank extends upward through the deck and terminates in a 3-in. male Ever-tite* bronze quick-connect fitting The sanitary and galley waste stored in the impoundment tank can then be transferred through a suitable suction hose coupled to the deck fitting.

Septic Tank Service Truck

In the absence of a fixed shore-based facility, a mobile pumping station in the form of a septic tank service truck can be used. These tank trucks are generally equipped with 100 to 150 feet of suction hose, compatible (Ever-tite) quick-connect couplings, and have more than adequate self-priming and suction lift capabilities.

Deck-Mounted Sewage Pump

To demonstrate alternate waste disposal methods, a deck-mounted sewage pump was provided, together with suitable suction and discharge hoses. In this way disposal into a dockside sewer or treatment plant could be demonstrated. In emergencies, or when the boat is at sea, overboard discharge is possible. For future incorporation into a completely tamperproof impoundment system, the same sewage pump can be operated with equal effectiveness as part of a portable shore-side pumping station. Because of the developmental nature of this installation, in terms of its ability to provide an adequate pump-out interval under all operating conditions, deck-mounting of the pump seemed appropriate.

Selection of a suitable sewage pump was based on its ability to meet the following requirements:

a. Capable of pumping out raw sanitary and galley waste immersed in sea water, via a 3-in. suction pipe, at a rate not less than 15 gpm. Maximum size solids to be encountered = 1-1/4 in.

b. Suction lift greater than or equal to 15 feet of water.

c. Discharge head greater than or equal to 10 feet of water.

d. Self-priming under the above conditions.

e. Compatible with sea water.

f. Capable of unrestricted operation in marine atmosphere.

g. Compatible with onboard power supply.

h. Relatively small, lightweight, and inexpensive.

A suitable pump, in terms of its ability to satisfy all the above criteria, is a Marlow Model 204 EC "Mud Hog" * 2 x 2-in. single diaphragm pump. Under the maximum suction and discharge pressures listed, this pump can provide a nominal flow rate of 20 gpm, and is capable of self-priming to a static suction lift of 20 feet of water. The pump diaphragm is made of nylon inserted natural rubber; replaceable rubber flapper valves are used for the inlet and outlet check valves. Since the gearcase and pump body were of cast iron construction, the vendor coated all parts in contact with the liquid to be pumped with an 18-mil. thick Scotchcoat #202 Epoxy* coating prior to assembly.

*Mention of commercial products does not imply endorsement by the Federal Water Pollution Control Administration.

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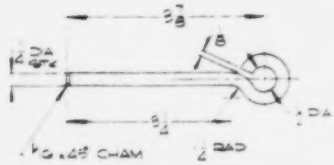
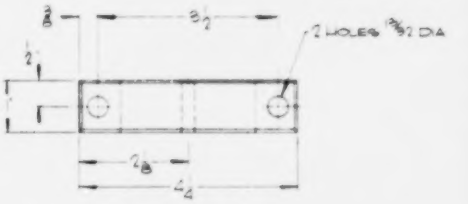
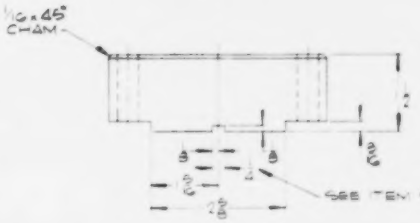


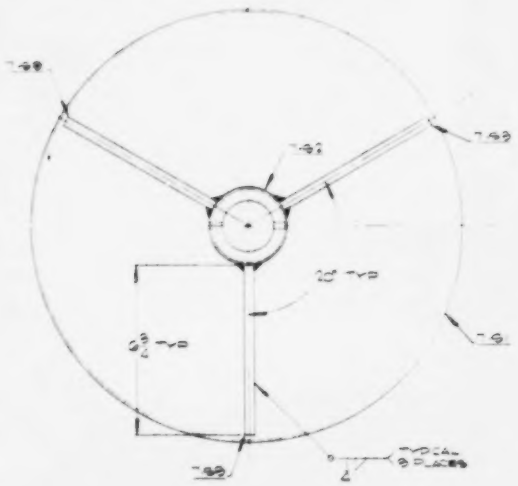
③ PIN LOCKING
SCALE: 1

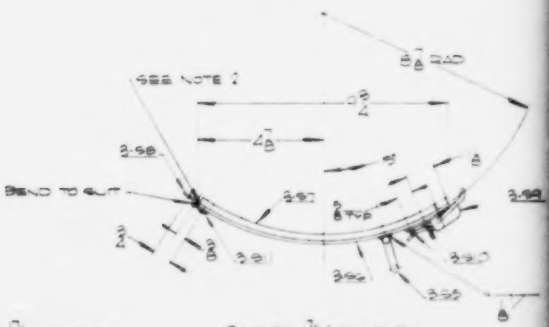


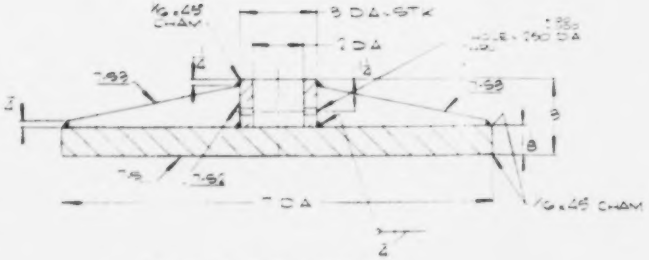


④ CAP FRONT
SCALE: 1

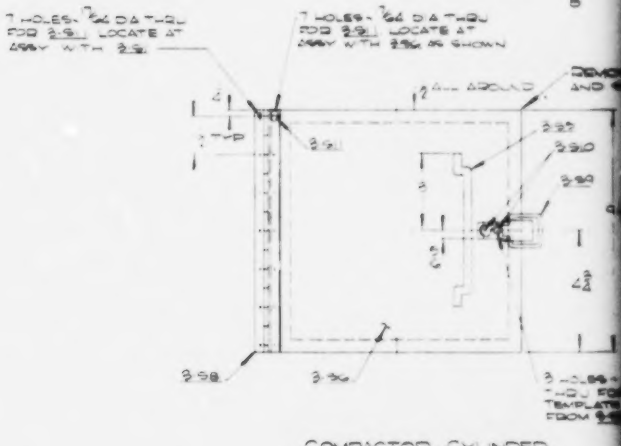
⑤ CAP REAR
NOTE: SAME AS ITEM 4 EXCEPT OMIT SLOT







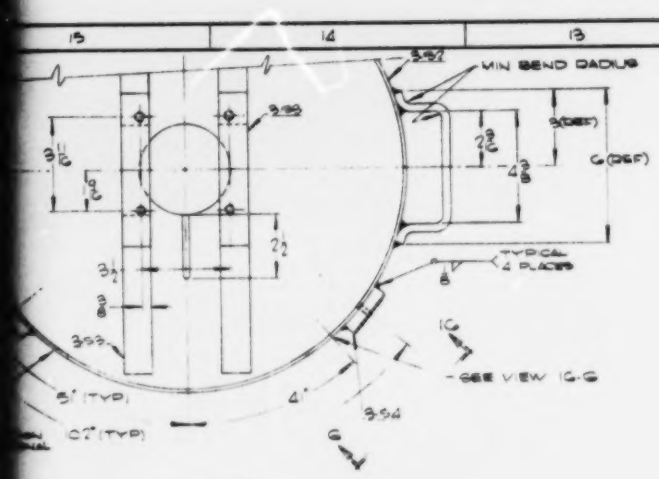
⑥ COMPRESSOR TRASH

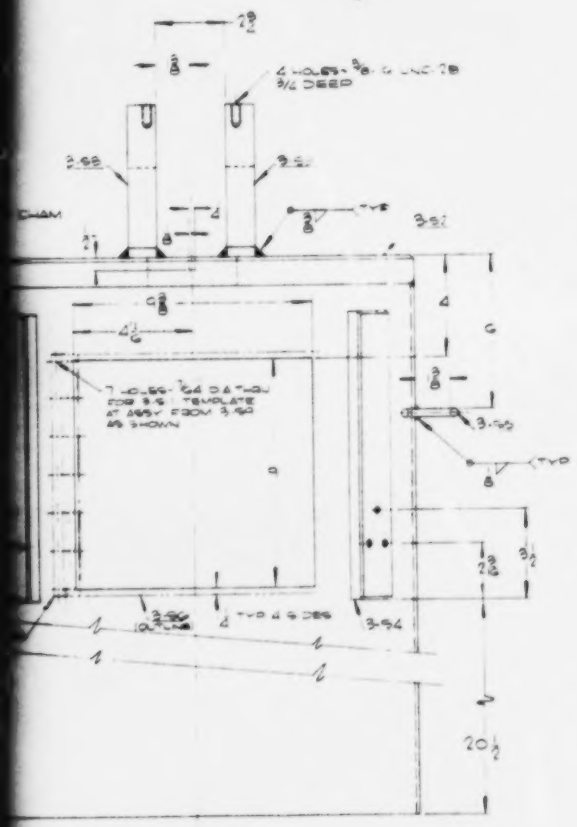


COMPACTOR CYLINDER
DOOR DETAIL

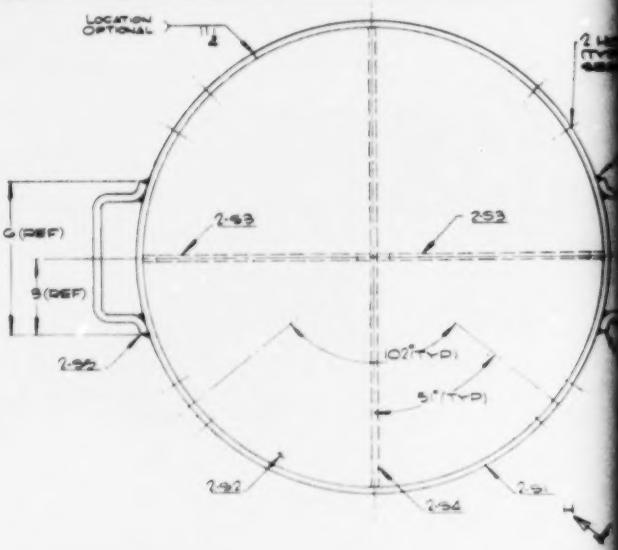
20
19
18
17
16
15
2 HOLES .782 DIA
1 HOLE-1/4-20 UNC-2B
1/16 x 45° CHAM
1/2 DIA CK
⑦ HANDLE, JACK REVERSING
SCALE-1/1
2 HOLES .564 DIA THRU FOR 3.90 TEMPLATE AT ASSY FROM 3.90 AS SHOWN
3.93
3.90
3.91
DRILL
DEF
2 HOLES-1/4-20 UNC-2B THRU TYP 2 PLACES
3.86
1/8 x 45° CHAM ALL AROUND
VIEW G-G
3.94
8-32 UNC 2B (4 PLACES)
3.93
.5" (TYP)
LOCATION DOT DIAL
.07" (TYP)
SEE ITEM 5
4 EXCEPT DMT SLOT
.8 RAD
3.90
3.90
3.95
.564 DIA THRU
LOCATE AT
AS SHOWN
REMOVE ALL BURRS AND SHARP EDGES
ALL AROUND
3.93
3.90
3.90
3 HOLES-.782 DIA THRU FOR 3.90 TEMPLATE AT ASSY FROM 3.90 AS SHOWN
ACTOR CYLINDER
OR DETAIL
3.93
3.90
.5 RAD
TYP
3.88
3.88
REMOVE ALL SHARP EDGES OF OPENING
3.90
DIA
8 x 45° CHAM
3.98
3.96
3.90
3.90
3.90
CYLINDER, COMP
2D5075

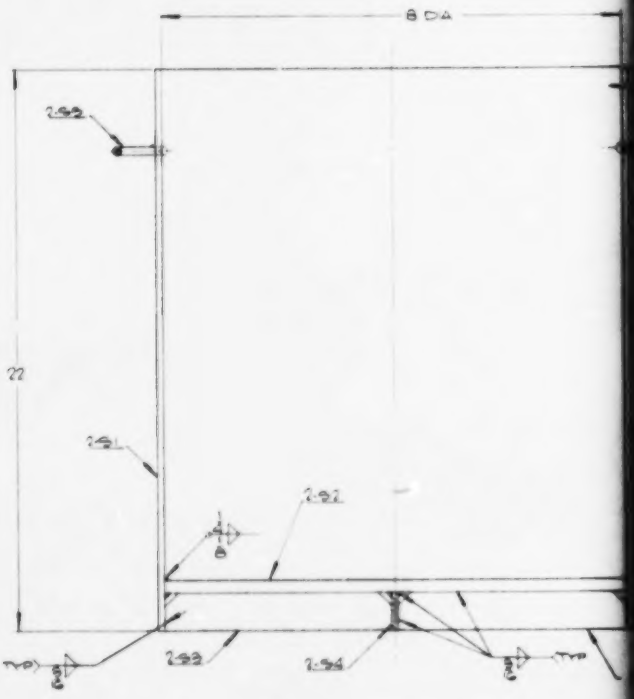
3/-32-



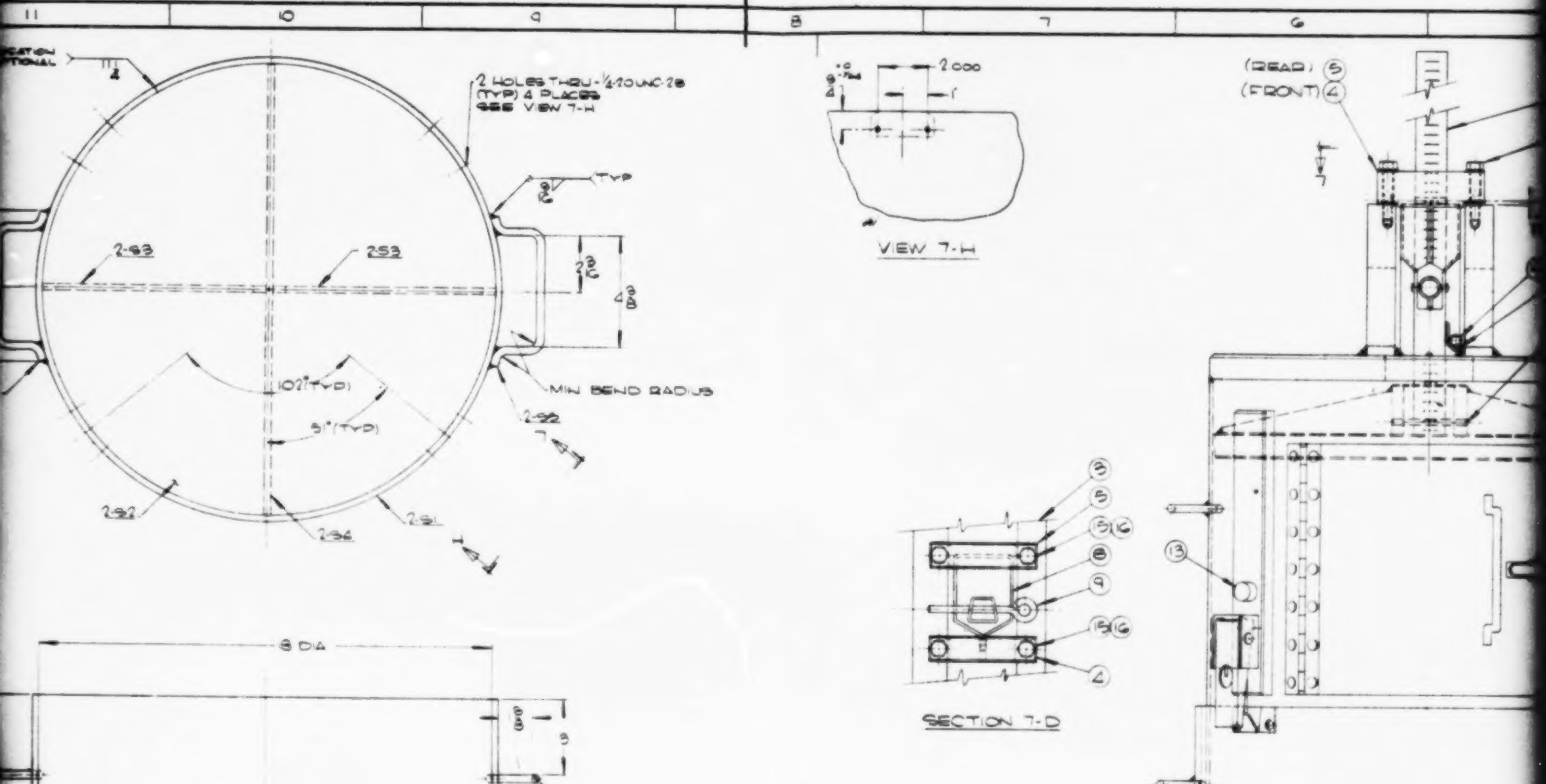


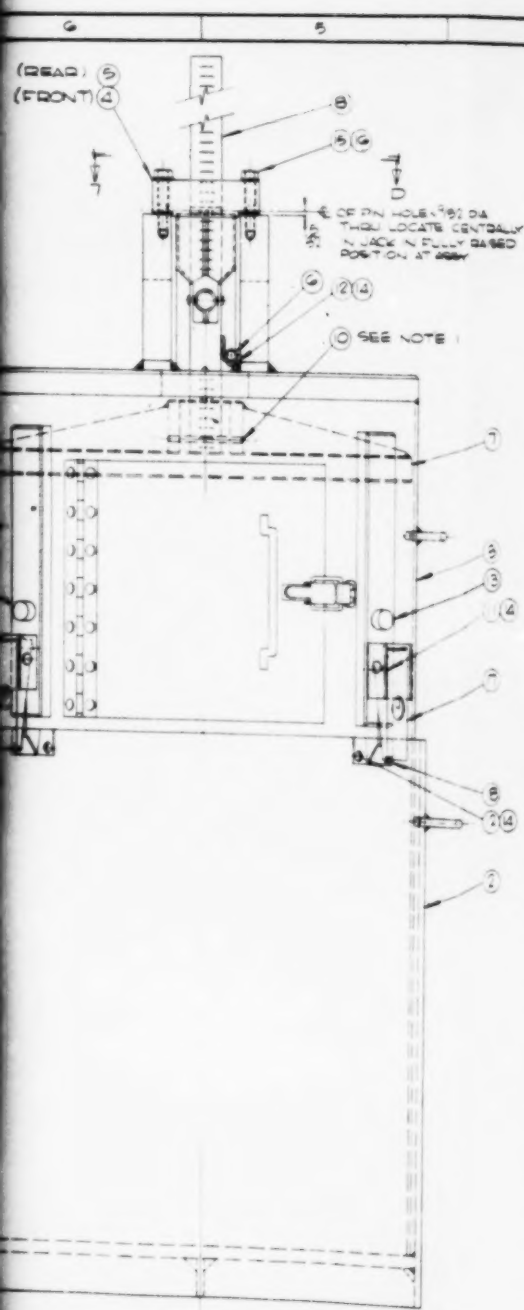
① CYLINDER, COMPACTOR





② CAN, COMPACTOR


11
10
9
8
7
6
2 HOLES THRU - 1/4-20UNC-2B (TYP) 4 PLACES SEE VIEW 7-H
(TYP)
2-S3
2-S3
2 3/16
4 3/8
10 1/2°(TYP)
51°(TYP)
MIN BEND RADIUS
2-S2
2-S2
2-S4
2-S1
2.000
1
VIEW 7-H
(REAR) 5
(FRONT) 4
3
5
15 16
8
9
15 16
4
13
SECTION 7-D
8 DIA
3
2-S5
2-S2
1/2 x 45° SNIPE (TYP)
2-S3
2-S4
(TYP)
2-S3
1 1/2
② CAN, COMPACTOR
① TRASH COMPACTOR AS
2D5075



① TRASH COMPACTOR ASSY

NOTES

1. JACK (ITEM 8) TO BE PINNED AND LOADED IN PLACE TO COMPRESSOR (ITEM 7) AT ASSY.
2. GASKET 2-07 TO BE CEMENTED TO DOOR 3-06 USING MINNESOTA MINING AND MFG Co EC-1357.
3. UNLESS OTHERWISE SPECIFIED ALL MACHINED SURFACES TO BE 125.
4. ITEMS WITH SUGGESTED COML SOURCES CAN BE PROCURED FROM EQUIVALENT APPROVED SOURCES.

THIS IS AN AS BUILT DWG

REVISIONS

LTR	DESCRIPTION	DATE	APPROVED

LIST OF MATERIAL

ITEM NO.	QTY	CODE IDENT NO.	PART OR IDENTIFYING NO.	DRAWING OR SPECIFICATION NO.	DESCRIPTION	MAT'L	REMARKS
-			3D5075-30		3060 COMPACTOR ASSY	-	
			3D5075-3001		CAN, COMPACTOR	-	
					PLATE - 1/4	AL	
					PLATE - 1/4	AL	
					BAR FLAT - 1/4 x 1 1/2	AL	
					BAR FLAT - 1/4 x 1 1/2	AL	
					ROD ROUND - 5/8 DIA	AL	
			3D5075-3003		CYLINDER, COMPACTOR	-	
					SHEET - 1/8	AL	
					PLATE - 1/8	AL	
					PLATE - 1/8	AL	
					PLATE - 1/2	AL	
					ROD ROUND - 5/8 DIA	AL	
					SHEET - 1/8	AL	
					GASKET - 1/4 - HC (CLOSED CELL)	SLABSTOCK	
					NYLON 1/8 x 3/4 x 2 1/2 LONG	NYLON	
		ELOR PLAC			CATCH, DRAW 2"	ZINC PLATED	CLOSED - OPEN LOCK DRAW MFG CORP
					RIVET, TUBULAR HD - 3/16 x 1/2 LG	SOFT	
					RIVET, BUTTON HD - 4 x 1/2 LG	SOFT	
			3D5075-304		CAP FRONT	AL	
			3D5075-305		CAP REAR	AL	
			3D5075-306		LIFTING JACK DECKPLATE	AL	
			3D5075-307		COMPRESSOR PLATE	-	
					PLATE - 3/8	AL	
					ROD ROUND - 3/8 DIA	AL	
					PLATE - 3/8	AL	
		56008	5D5075A-308		JACK ASSY	STEEL	SEE 5D5075A-308
		56008	5D5075A-309		PIN, LOCKING	SOFT	
			3D5075-310		PIN	NI-CU	3/8" MDN x 3 1/4" LG - .344 DIA @ 1" FROM ENDS
					SCREW SOC HD - 1/4-20 UNC - 3/8 LG	NI-CU	
					SCREW SOC HD - 1/4-20 UNC - 1/2 LG	NI-CU	
					BUTTON MAGNET CATCH 7/16 DIA		
					WASHER LOCK - 1/4	NI-CU	
					SCREW - 6X HD - 3/8 SLOT - 1/2 LG	NI-CU	
					WASHER LOCK - 3/8	NI-CU	
					LATCH ASSEMBLY	SOFT	
					HOOK	SOFT	

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED

MACHINED			WELDMENT		CASTING	
DIMENSION	ISO CODE	FRACTIONS	DIMENSION	TOLERANCE	DIMENSION	TOLERANCE
UNDER 6"	±.010	±.030	UNDER 24"	±1/16"	UNDER 2"	±1/16" - 1/16"
6" TO 24"	±.020	±1/16"	24" & OVER	±1/8"	2" TO 5"	±3/32" - 1/16"
24" & OVER	±.030	±1/8"	ANGULAR ±1° 30'		5" TO 9"	±1/8" - 3/32"
ANGULAR ±1° 30'					9" TO 15"	±3/16" - 1/16"
					15" & OVER	±1/16" - 1/16"

THIRD ANGLE PROJECTION — CONTROL SYMBOL MIL STD 100

DRAWN	W SHELDON 3/6
TRACED	
CHKD	
APPD	
CUSTOMER	
DATE AS TYPE	DRAWING

MATERIAL SPECIFICATIONS

Electric Steel Division

TRASH COMPACTOR ASSEMBLY & DETAILS

DATE	SIZE	CODE IDENT NO.	DRAWING NO.	REV
	H	95169	3D5075	-

SCALE 1 AND AS NOTED — SHEET 1 OF 1

Primarily because of the long delivery times (3 to 4 months) associated with marine dc motors, an equivalent air motor was chosen to drive the pump. In accordance with the pump manufacturer's recommendations, a Gast Model 2 AM-NCC-43 rotary air motor with NEMA 56C flange mounting was specified. The unit is rated at 1/2 hp at 1750 rpm, and requires 17 cfm of "free air" consumption at 70 psig. This requirement is well within the capability of the ship's air compressor, which can deliver 25 cfm at 100 psig. The air motor was supplied with the manufacturer's recommended accessories consisting of a 2F122B filter; manual drain, 1/4 in.; a 2R000AG regulator, 1/4 in. with AA806 gage; and a 2L000 lubricator, 1/4 in. Use of an air motor vs an equivalent dc motor has the additional benefits of greater compactness and lower cost.*

Installation of the air motor-driven diaphragm pump is shown in Figure 18. It is a relatively compact unit requiring a volume envelope of approximately 15 x 19 x 16 in. It is shown connected to the deck pump-out fitting via a short length of flexible, reinforced-rubber suction hose fitted with Ever-tite bronze quick-connect couplings. The air motor ancillaries, including a 1-in. bronze control valve, are located alongside the pump.

PIPING AND WIRING SYSTEMS

All the required piping and wiring systems associated with the interconnection of the primary system components and their connection to the appropriate ship's services are illustrated in Figures 1, 2, and 6. A brief description of the pertinent characteristics of each system is presented in the following paragraphs.

Figure 18. Deck-Mounted Sewage Pump

*Mention of commercial products does not imply endorsement by the Federal Water Pollution Control Administration.

Piping Systems

Unless otherwise specified, 70-30 Cu-Ni piping and bronze fittings and valves were used throughout to provide the necessary protection against salt water corrosion. All Cu-Ni piping to fitting joints was silver brazed. Flange gaskets made from neoprene or Buna-N* rubber were used. All deck penetrations were made using silver brazed bronze flanges. The deck was counterbored in way of deck penetrations to a depth equal to the flange thickness and a coating of white lead applied for proper sealing.

Sanitary and galley wastes are transported to the impoundment tank via 3-in. Cu-Ni piping. Sweep tees and 45-degree elbows were used to avoid sharp corners. Where possible, the drainage piping was pitched 1/2-in. per foot.

Use of plastic PVC piping was considered as a means of reducing costs, but was rejected because:

a. Previous experience with PVC drainage piping installations onboard submarines indicated maintenance problems associated with leaking joints. These problems are presumably related to the susceptibility of plastic joints to mechanical vibrations.

b. The additional operating costs attributable to the increased maintenance anticipated with PVC piping can easily offset the lower initial cost.

All piping running to or through the impoundment tank cover including the 3/4-in. flush line, 1-in. vent line, 1/4-in. air line, and 3-in. drain and discharge lines was provided with flanged connections, as close to the cover as possible, to facilitate tank removal.

Cu-Ni piping (1/4 in.) was run from the ship's air compressor to the flush control valves, bubble tube, and level gages. In addition to an air filter, two lubricators were installed to ensure adequate lubrication of each of the four pneumatic operators. Flexible polyethylene P-tubing was used inside the alarm and master control station enclosures to permit opening of the cover and for ease of installation. A 1-in. Cu-Ni line was run from the compressor to the pump's air motor and included a manual control valve, air filter, lubricator, and pressure gage.

Three inch suction and discharge hoses were selected for use with the 2-in. diaphragm pump in order to:

a. Preclude any possibility of clogging with solid waste material upstream and downstream of the sewage pump.

b. Minimize the pressure drop and thereby facilitate tank pump-out under all conditions.

c. Ensure compatibility with shore-based pumpers.

Wiring System

The electrical interconnection of the alarm and control stations, pushbuttons, control valves, power supply, and pump motor contactor is delineated in Figure 19. Eighteen gage wire, enclosed in marine type armored steel cable, was used between all terminal board connectors. Twenty gage wire was used for all internal wiring. The current drain imposed by the system is very small. Each control valve, relay, or timer consumes about 40 ma when operating. The photocell operates with a continuous power drain of only 0.3 w.

*Mention of commercial products does not imply endorsement by the Federal Water Pollution Control Administration.

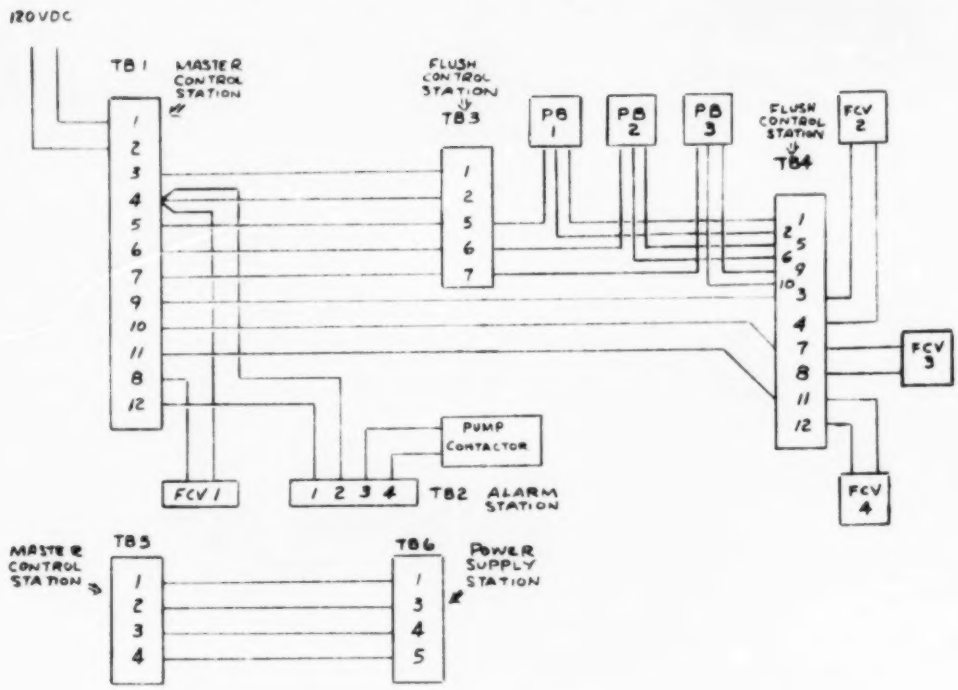


Figure 19. Cable Diagram

SECTION 5

OPERATIONAL TESTING AND EVALUATION

CONTROL SYSTEM ADJUSTMENT AND CALIBRATION

Following the installation of the entire waste impoundment system, various manual controls and time delay relays associated with the master control and flush control stations had to be adjusted, and each volume control valve had to be calibrated.

Level Sensing System

The rate of air flow to the bubble tube was adjusted at the flow controller to provide a minimum flow consistent with satisfactory operation. A flow rate setting of 0.5 cfh was selected corresponding to a bubble rate of approximately two bubbles per second. The small pressure and flow perturbations at the bubble tube and flow controller had no apparent effect on the level gage readings.

Master Control Station

The high and low level indices which appear on the photohelic gage are adjustable from 0 to 60 in. The high level alarm index was set at the 54-in. level (108 gallons), approximately 90 percent of tank capacity. The low level index, which controls starting of the automatic flush, was set at the 4-in. level. The total volume of sea water delivered to the tank during flushing is determined by the flow rate through the manifold and the length of time the control valve is energized. A flush rate of 15 gpm was determined by using the level gage as a cumulative flow indicator. The control valve was then calibrated to deliver 25 gallons of flush water with a timer setting of 100 seconds. With all permissive switches in the ON position, a total flush of 80 gallons can be attained in the same 100-second interval.

Sanitary Flush Control Station

Minimum and maximum flush volumes to suit each sanitary facility were obtained by adjusting the corresponding short and long flush timers, and the rate of closure of the modified control valves. Short flush times (0 to 10 sec) for the water closets were set to provide minimum flush volumes consistent with little or no solids (micturition). Long flush times (1 to 20 sec) were set to handle the maximum anticipated needs of the operator (defecation). The rate of closure of the modified valves was reduced sufficiently so as to eliminate water hammer, facilitate solids removal, and fill water seal to proper level.

Each control valve was calibrated by means of the tank level gage and elapsed time indicators. The actual flush times and volumes used for each water closet and urinal are shown in Table 1. Also included are the corresponding delay timer settings.

Table 1. Sanitary Flush Control Times and Volumes

	Short Flush		Long Flush		Delay Time, Minutes
	Volume, Gallons	Time, Seconds	Volume, Gallons	Time, Seconds	
Water Closet No. 1	2.6	1.4	4.5	5.1	4
Water Closet No. 2	2.3	1.6	4.0	4.2	4
Urinal	0.12	1.0	0.2	1.7	2

The flush control times listed above correspond to the time during which the solenoid valve is energized, and does not correspond to the duration of a complete flush.

OPERATING RECORDS AND TEST EQUIPMENT

Operating data taken by the crew under routine operating conditions was recorded daily on an appropriate log sheet. Sufficient information was gathered over a two-month period (mid-November to mid-January) to establish the effectiveness of the various system components.

Appropriate log forms were used for each sanitary facility, tank pump-out and automatic flush, and the trash compactor. For each usage of the water closet or urinal, the time and type of flush was recorded on a daily log sheet. Whenever the impoundment tank was pumped out, the following information was recorded:

a. Date and time of day.

b. Tank level and total pump-out time.

c. Type and number of tank flushes.

d. Sanitary flush control valve elapsed time readings.

e. Mode of pump-out.

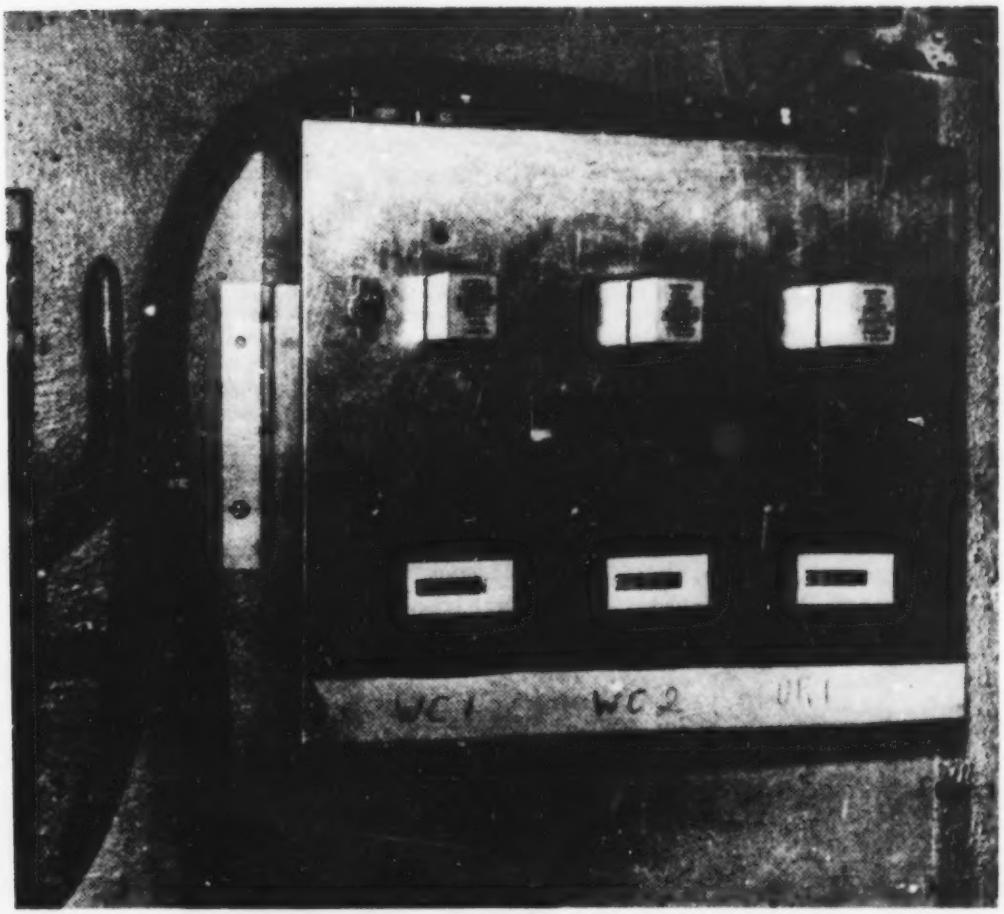


Figure 20. Water Closet and Urinal Event Timers

Three digital elapsed time indicators were installed to provide the data for item d (see Figure 20). These timers were furnished as test equipment, and as such, are not a permanent part of the system. Each timer indicated the total time, in tenths of a second, that each corresponding flush control valve had been energized. Thus the relative contributions of each sanitary facility to the total volume of sanitary and galley waste accumulated in the tank was continuously monitored.

The operating effectiveness of the trash compactor was monitored by recording the frequency of compaction and the level after each compaction.

EQUIPMENT PERFORMANCE ANALYSIS

A discussion of the operating effectiveness of the waste impoundment system installed on the Three Deuces and demonstrated during the two-month test period is presented below. The analysis has been broken down into an evaluation of each of the primary subsystems and components and includes an analysis of the operational test data recorded by the crew.

Waste Impoundment Station

The design and construction of the 120-gallon holding tank proved to be completely satisfactory in terms of:

a. Storage capacity. The frequency of tank pump-out with a normal crew of five, operating approximately 12 hours per day, varied from two to five days. This rate is equivalent to an accumulation of 4 to 10 gallons per man per day. To service larger crews under the same storage space limitations, the use of form-fit tanks might be considered, despite the higher initial cost.

b. Efficient transfer of liquid and solid wastes. No clogging or plugging of the suction pipe was noted. Also no accumulation of solids at the bottom of the tank or on internal surfaces was in evidence.

c. Corrosion resistance. All internal and external surfaces appeared free from corrosion, and the tarset coating suffered no noticeable deterioration.

d. Air and water tightness. No traces of odor nor evidence of leaking were observed throughout the test phase.

Periodic inspection of the inside surfaces of the tank through the Plexiglass viewport before, during, and after flushing indicated that all surfaces were flushed and cleaned satisfactorily by the spray from the perforated pipe ring. No tendency for the flush manifold to clog was noted as indicated by an undiminished flush rate (15 gpm) throughout the test period. If an increased flush rate is desired, a substantial increase in the number of perforations can be permitted without a significant decrease in impingement velocity or uniformity of flow distribution.

The activated carbon filter served as an effective odor seal while venting the impoundment tank with minimal pressure drop during normal operation. At no time during the two-month period were any traces of odor detected by the crew. At the end of the test period, the 5-lb bag of carbon was still performing effectively. Preliminary estimates indicated that a 5-lb bag of activated carbon should last for a period of at least 5 to 6 months. The actual replacement interval will vary depending on the frequency of pump-out, engine room and atmospheric temperatures, etc.

Pressure drop through the carbon filter during pump-out was observed by noting the fluctuations in water closet trap levels. Operation of the diaphragm pump (7 cfm) gave rise to fluctuations of from 1/2 to 1 in. of water. A pressure drop of approximately 3/4 to 4 in. of water was observed when a septic tank truck was used to pump out the tank (17 cfm). The insertion of a 6-in. diameter support screen raised the bag of activated carbon sufficiently to decrease the pressure drop to approximately 1 in. of water.

The level sensing system performed accurately and reliably throughout the entire test period. Once adjusted, the differential flow-controller provided a steady, uninterrupted flow of air at a rate of 0.5 cfh to the bubble tube under all observed conditions. The 25 ft^3 compressor surge tank provided sufficient air for continuous operation during periods when the ship's power was shut down. The readings of both level gages appeared to be insensitive to both the ship's motion and the discontinuity of single bubble formation. The crew considered the additional level gage at the alarm station desirable for continual and convenient monitoring of the tank level.

Master Control and Alarm Stations

All control and alarm equipment, once installed and calibrated, performed as designed without further adjustment or modification. Operation of the master control station, located outside the deck house with overhead shelter, was apparently unaffected by the rather severe weather encountered during the test phase.

Although the sea water pump remained de-energized throughout the high level condition, a sufficient quantity of flush water was available from the surge tank to permit several additional sanitary flushes, if needed. During tank pump-out, an automatic flush (25 gallons) of the tank through the flush manifold was generally followed by a total flush (80 gallons) as indicated in Figure 10. The second automatic flush ensured a thorough flushing of the drain lines, suction line, and transfer hose.

Sanitary Flush Control System

The short and long flush timer settings listed in Table 1, once adjusted and set early in the test period, remained unchanged throughout. Since the sea water pressure was controlled within ±5 psi of the nominal (30 psi), pressure variations during flushing had a negligible effect on the reproducibility of flush volumes. Periodic checks of the flush times and volumes indicated that both the timer and needle valve settings were stable throughout the test period.

The urinal and water closet flush control valves were installed below deck, and the water closet valves modified as shown in Figure 14. The flush control station performed as designed in each of the three control modes, energizing and de-activating each valve for the appropriate period of time. The control valves functioned flawlessly throughout the test phase. The reduced rate of closure characteristic of the modified control valves, though adequate in terms of providing for shockless closing, filling of the trap, and solids removal, was considered less than optimum in terms of the latter function. A control valve modification which provides for a decreasing rather than linear rate of closure with time would have permitted the use of somewhat lower water closet flush volumes. Such additional refinements, however, were outside the scope of this program.

The results of the operational test data concerning the effectiveness of the sanitary and galley waste volume control devices are summarized in Table 2. The sanitary waste volume contributions are based on the elapsed time data and the flush volume calibrations. The galley sink contribution to the total was determined by difference. The results can be used to estimate holding tank capacity requirements for a particular size crew and desired pump-out interval.

The results also definitely establish the practicability of a waste impoundment system for commercial vessels of this class and size. Based on preliminary data obtained before the installation of the waste impoundment system, the results shown in Table 2 represent an estimated reduction of at least 50 percent in the total volume accumulation rates.

The tabulation also indicates that a further reduction in water closet flush volumes would have the largest impact on the total accumulation rate. For example, a 50 percent reduction in both short flush and long flush volumes would reduce the total accumulation rate by over 30 percent. Reductions of this magnitude can probably be accomplished through the replacement of existing water closets with those having smaller and shallower traps and a more efficient flushing action. Such water closets have been in use in the United Kingdom for many years and are being introduced in this country for domestic use.

Table 2. Results of Waste Volume Control Data

	Average Volume Contribution Gallons	%	Average Volume Per Man Per Day* Gallons
Water Closets (2) Flush	69.0	61	4.6
Urinal Flush	9.2	8	0.6
Sanitary Waste	4.8	4	0.3
Total Sanitary Waste	83.0	73	5.5
Galley Sink	30.0	27	2.0
Total	113.0	100	7.5

Average pump-out interval: 3.0 days

Average crew size: 5 men

*Based on an average of 12 hours per day occupancy.

Further reductions in sanitary flush volumes can only be achieved by the use of a more efficient and conceptually different approach to waste transfer, such as the vacuum flush system. In a system of this type, wastes are air transported from specially designed water closets to a receiving tank by a central vacuum system with the use of only 1/2 gallon of water per flush. Inclusion of such a vacuum flush system could reduce the total volume accumulation rate from 7.5 to about 3.5 gallons per man-day.

It should be noted that the data summarized in Table 2 is based on a normal operating schedule for the Three Deuces requiring an average occupancy of about 10 to 12 hours per day. Occasional trips to other ports, requiring an occupancy of 24 hours per day, would result in increased volumes per man-day. Although the total sanitary waste volume is not expected to change significantly, the increased galley activity could easily double the galley sink contribution, and thereby decrease the pump-out interval to about 2 days or less.

Galley Waste Control Equipment

Storage of the solid galley waste in the specially designed trash compactor was a satisfactory and practical means of increasing effective storage capacity. The ease with which the compactor crushed tin cans, glass bottles, etc, was amply demonstrated onboard the Three Deuces as well as in pre-installation testing. Results of the testing showed that an average of two weeks' worth of solid galley waste can be stored in the compactor before removal of the compressed garbage in its plastic bag. Based on an observed compaction ratio of about 5:1, this amount is equivalent to approximately 14 ft^3 of uncompacted galley waste.

Operation of the unit was relatively easy. Safe handling by a single individual was ensured by installing a counterweight assembly whose weight balanced that of the cylinder and compactor assemblies (not over 100 lb). The entire compaction operation can be performed in about 30 to 60 seconds. Removing compacted garbage and inserting an empty plastic bag can be done in less than 2 minutes. The use of relatively strong plastic bags (at least 5 mils thick) to minimize the possibility of tearing is recommended. It was also found advantageous to spray a thin film of Teflon onto the inner surface of the inner cylinder to facilitate extraction of the compacted garbage.

Operation of the self-closing spray nozzle in conjunction with the galley sink mixing valve was judged to be adequate for the needs of the crew under normal operating conditions in terms of operating convenience and adequate flow rates. The exclusive use of a spray nozzle for the needs of a larger galley and crew might become inconvenient. In such a situation, the use of two separate (hot and cold) self-closing valves with a single swinging spout is recommended.

Pump-Out Station

The primary mode of emptying the impoundment tank during the two-month test period was by means of the deck-mounted sewage pump. In the absence of accessible sewer lines, transfer of wastes to a sewer system was simulated by pumping into a portable 1500 gallon dockside storage tank via 100 feet of collapsible rubber-lined hose. On occasion, circumstances dictated pump-out of the tank while at sea. A septic tank pumper was used on a rather limited basis largely because of the irregularity of the Three Deuces work schedule.

The capability of tank pump-out by a septic tank truck was established early in the test period. Compatibility with the impoundment system in terms of mating to the quick-connect deck fitting and efficient pump-out of the holding tank was successfully demonstrated (see Figure 21). A maximum pump-out rate of 120 gpm was observed. A total pump-out time of approximately 5 minutes was largely determined by the length and number of tank flushes.

The air motor-driven diaphragm pump performed more than adequately. The pump speed, controlled by a globe valve on the 1-in. air line to the motor, reached a maximum at a 30-gpm delivery rate. The pump primed itself in a matter of seconds and proceeded to pump out the tank, with two automatic flushes, in an average total time of about 8 minutes. Quick-connect fittings were used to couple both the suction and discharge hoses to the pump inlet and outlet, as shown in Figure 18, and provided water-tight and air-tight seals on both ends.

The pump's drain plug was replaced with a petcock to facilitate drainage of water from the pump body after each use. To maximize the rate of air flow to the motor inlet, a 1-in. air (moisture) filter was used in place of the standard 1/4-in. size, and the lubricator installed in a parallel loop as shown in Figure 22. In very cold weather, "icing" of the air exhaust muffler necessitated its temporary removal during pump-out.

NORMAL SYSTEM MAINTENANCE

A minimal amount of routine maintenance is required to keep the system fully operational. The actual amount of time involved is, for all practical purposes, negligible by comparison with the crew's normal maintenance routine. Those items which require regular or periodic inspection and servicing are listed below:

a. Lubricators. Check level of oil in air line lubricators feeding the control valves and the air motor periodically, and refill to proper level as required.

b. Air Filters. Check level of condensate in air filters periodically, and drain as required.

c. Carbon Vent Filter. Check for unpleasant odors emanating from the tank vent. Estimated frequency of replacement of 5-lb carbon bag is about once every 6 months. Actual replacement time is approximately 2 minutes.

d. Diaphragm Pump. Drain water from pump body after each use. Change gear oil every 500 hours of operation or twice a year (every summer and winter). Grease pump rod alemite fitting every 100 hours of operation.

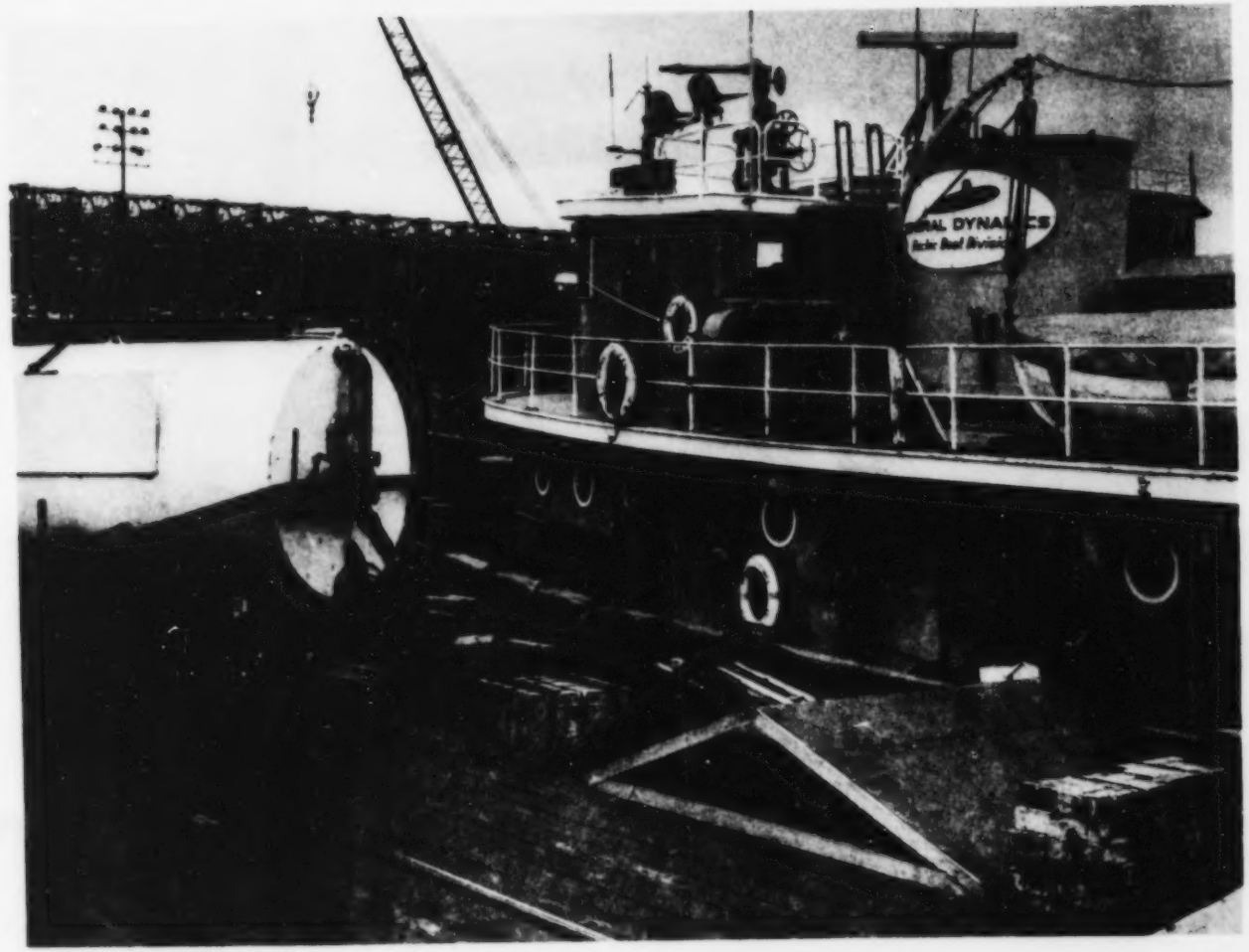


Figure 21. Pump-out by Septic Tank Truck

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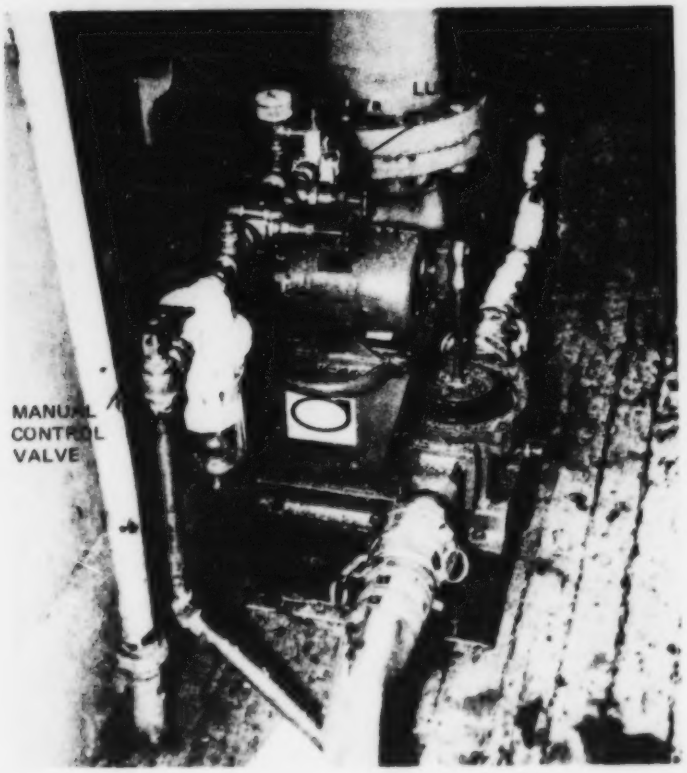

Figure 22. Pump Air Motor Accessories

SECTION 6

SYSTEM COST SUMMARY

INITIAL COST

A summary of the initial costs within each subsystem, including material, fabrication, and installation costs is presented in Table 3. The total initial cost of the entire waste impoundment system installed onboard the Three Deuces amounts to $8,970. Approximately 65 percent ($5,875) of the total cost is attributable to the impoundment and transfer functions (including tank flushing). The remaining 35 percent is associated with the sanitary and galley waste control systems.

Due to the developmental nature of this program and the fact that the demonstration system is essentially a custom-made unit, the costs shown in Table 3 are necessarily conservative, especially with regard to Items A and D. With the experience gained from this program, cost effective modifications coupled with large-scale production should decrease the cost of components such as the impoundment tank and trash compactor by 50 to 75 percent.

The costs shown in Item F (piping and wiring systems) reflect, to a large extent, the location of the various components relative to existing ship's services and sanitary and galley facilities, and can vary substantially with each installation. These costs also reflect installation on a non-interference basis (100 percent availability of the vessel). Due to the limited availability of the Three Deuces, the actual charges incurred were greater.

OPERATING COSTS

The system operating costs,excluding tank pump-out, are those associated with the following consumable items:

Activated carbon	= $30 per year
Plastic bags and chemical disinfectant (trash compactor)	= $19 per year
Lubrication fluid (air lines)	= $2 per year
Compressed air*	= $3 per year
Electrical power	= $1 per year
Total	= $55 per year

*Based on allowance for operation of the ship's air compressor. Activated carbon costs can be reduced to approximately $10 per year by purchasing 200-lb drums of a standard commercial grade activated carbon.

The cost of tank pump-out will depend on the specific mode used. Alternate methods and corresponding costs are listed in Table 4. The cost of operating the deck-mounted pump includes an allowance for operation of the ship's air compressor, for pump gear oil, and air motor lubricant. The yearly operating cost (using transfer mode A) would then total $70. The yearly cost of regular pump-out by a septic tank pumper on an individual or group basis is obviously expensive for vessels of this size. In the absence of dockside sewer lines or waste treatment facilities, transfer to a dockside holding tank for monthly pump-out by a septic tank truck will reduce the cost substantially.

Table 3. Summary of Capital (Initial) Costs

Subsystem/Component	Material/ Component Cost ($)	Fabrication/ Assembly Cost ($)	Installation Cost ($)	Total Cost ($)
A. Impoundment Station				
Impoundment Tank	125	425	150	
Flush Manifold	20	100	–	
Vent Filter	35	55	–	
Total	181	580	150	910
B. Tank Control Systems				
Master Control Station	212	225	85	
Alarm Station	55	130	45	
Level Sensing System	70	–	30	
Flush Control Valve (1)	113	–	15	
Total	450	225	175	880
C. Sanitary Control System				
Flush Control Station	261	160	120	
Flush Control Valves (3)	334	–	140	
Total	595	160	260	1,015
D. Galley Waste Control				
Trash Compactor	75	1,335	50	
Galley Sink Faucet	25	–	15	
Total	100	1,335	65	1,500
E. Pump-Out Station				
Pump and Air Motor	620		45	
Suction and Discharge Hose	230		–	
Quick-Connect Fittings	90		–	
Total	940		45	985
F. Piping and Wiring Systems				
Piping, Fittings, Valves	1,375		1,650	
Electrical Wiring	105		550	
Total	1,480		2,200	3,680
Grand Total	$3,745	$2,330	$2,895*	$8,970

*Based on an average labor rate of $6.50 per hr.

Table 4. Tank Pump-out Alternatives

A.	Deck-mounted (or portable) pump =	$15 per year
B.	Septic tank pumper	
	1. Regular pump-out on individual basis = $45 per pump-out x 100 pump-outs per year =	$4,500 per year
	2. Regular pump-out on group basis = $25 per pump-out x 100 pump-outs per year =	$2,500 per year
	3. Transfer to and monthly pump-out of 1,500 gallon dockside storage tank = $45 per pump-out x 12 pump-outs per year = $540 per year + $15 per year (Item A) =	$555 per year

SECTION 7

ACKNOWLEDGEMENTS

This project was carried out by General Dynamics' Electric Boat division under Contract No. 14-12-509 for the Federal Water Pollution Control Administration, Department of the Interior. Harold Wallman was Project Manager and Sheldon Cohen was Project Engineer.

Acknowledgement is made of the support and assistance of James R. Bailey, Sanitary Engineer; Jean Mador, Sr. Mechanical Engineer; Russell J. Nickerson, Instrumentation Supervisor; William E. Thayer, Electrical Engineer; and the crew of the Three Deuces tugboat for their cooperation during the installation and operational phase of the project.